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(54) Member separating apparatus and processing apparatus

(57) This invention is to prevent a substrate from dropping when it is transferred/received to/from a separating apparatus. The support surfaces of substrate holding portions (22, 23) are made horizontal, and a substrate (21) to be separated is mounted on one substrate holding portion (22) in a horizontal state (2A). The substrate holding portions (22, 23) are pivoted about rotary shafts (26, 27), respectively, to make the support surfaces of the substrate holding portions (22, 23) vertical so that the substrate (21) is sandwiched by the substrate holding portions (22, 23) (2B). The substrate holding portions (22, 23) are rotated about rotary shafts (24, 25), respectively, and simultaneously, high-pressure, high-speed water is ejected from an ejection nozzle (28) to separate the substrate (21) into two substrates (21a, 21c). The substrate holding portions (22, 23) are pivoted about the rotary shafts (26, 27), respectively, to make the support surfaces horizontal (2C). With this arrangement, the substrate can be supported from the lower side and transferred in the horizontal state.

FIG. 1A



FIG. 1B



FIG. 1C



FIG. 1D

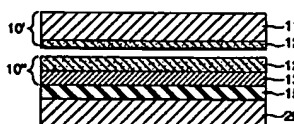


FIG. 1E



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## Description

### BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

[0001] The present invention relates to a member separating apparatus and processing apparatus, member separating method, and semiconductor substrate manufacturing method.

### DESCRIPTION OF THE RELATED ART

[0002] A substrate (SOI substrate) having an SOI (Silicon On Insulator) structure is known as a substrate having a single-crystal Si layer on an insulating layer. A device using this SOI substrate has many advantages that cannot be achieved by ordinary Si substrates. Examples of the advantages are as follows.

- (1) The integration degree can be increased because dielectric isolation is easy.
- (2) The radiation resistance can be increased.
- (3) The operating speed of the device can be increased because the stray capacitance is small.
- (4) No well step is necessary.
- (5) Latch-up can be prevented.
- (6) A completely depleted field-effect transistor can be formed by thin film formation.

[0003] Since an SOI structure has the above various advantages, researches have been made on its formation method for several decades.

[0004] As one SOI technology, the SOS (Silicon On Sapphire) technology by which Si is heteroepitaxially grown on a single-crystal sapphire substrate by CVD (Chemical Vapor Deposition) has been known for a long time. This SOS technology once earned a reputation as the most matured SOI technology. However, the SOS technology has not been put into practical use to date because, e.g., a large amount of crystal defects are produced by lattice mismatch in the interface between the Si layer and the underlying sapphire substrate, aluminum that forms the sapphire substrate mixes in the Si layer, the substrate is expensive, and it is difficult to obtain a large area.

[0005] A variety of SOI technologies have been introduced next to the SOS technology. Various techniques have been examined about these SOI technologies aiming at decreasing crystal defects and reducing the manufacturing cost. Examples of the techniques are as follows. First, oxygen ions are implanted into a substrate to form a buried oxide layer. Second, two wafers are bonded via an oxide film, and one of the wafers is polished or etched to leave a thin single-crystal Si layer on the oxide film. Third, hydrogen ions are implanted from the surface of an Si substrate having an oxide film to a predetermined depth, the substrate is bonded to

another substrate, a thin single-crystal Si layer is left on the oxide film by heating or the like, and the bonded substrate (the other substrate) is peeled.

[0006] The present applicant has disclosed a new SOI technology in Japanese Patent Laid-Open No. 5-21338. In this technology, a first substrate prepared by forming a nonporous single-crystal layer on a single-crystal semiconductor substrate having a porous layer is bonded to a second substrate via an insulating layer (SiO<sub>2</sub>). After this, the substrates are separated at the porous layer, thereby transferring the nonporous single-crystal layer to the second substrate. Advantages of this technology are that the film thickness uniformity of the SOI layer is excellent, the crystal defect density in the SOI layer can be reduced, the surface planarity of the SOI layer is good, no expensive manufacturing apparatuses with special specifications are required, and SOI substrates having SOI films having a thickness of several hundred Å to 10 μm can be manufactured by one manufacturing apparatus.

[0007] The present applicant has also disclosed, in Japanese Patent Laid-Open No. 7-302889, a technique of bonding the first and second substrates, separating the first substrate from the second substrate without destroying the first substrate, smoothing the surface of the separated first substrate, and forming a porous layer again to reuse the first substrate. In this technique, the first substrate is not wasted, and therefore, the manufacturing cost can be largely reduced, and the manufacturing process can also be simplified.

[0008] To facilitate mass production using the above techniques, factors to lower the yield must be minimized. For example, in a series of processes of separating a bonded substrate stack at a porous layer, it is important to avoid risks of substrate drop.

### SUMMARY OF THE INVENTION

[0009] The present invention has been made in consideration of the above situation, and has as its object to provide a separating apparatus and method suitable to separate member such as substrates, a processing apparatus suitable to process members such as substrates, and a semiconductor substrate manufacturing method using the separating method.

[0010] According to the present invention, there is provided a member separating apparatus characterized by comprising manipulation means for changing a direction of a major surface of a member, and separation means for separating the member using a stream of a fluid, wherein the manipulation means has a function of manipulating the member to match the direction of the major surface with a first direction and a function of manipulating the member to match the direction of the major surface with a second direction.

[0011] In the separating apparatus, the manipulation means preferably receives the member with the major surface whose direction matches with the first direction,

matches the direction of the major surface with the second direction, and moves the member to a position where the separation means can process the member, and also matches a direction of a major surface of at least one member of the members separated by the separation means with the first direction.

[0012] In the separating apparatus, the manipulation means preferably receives the member with the major surface whose direction matches with the first direction, matches the direction of the major surface with the second direction, and moves the member to a position where the separation means can process the member, and also matches directions of major surfaces of members of the members separated by the separation means with the first direction.

[0013] In the separating apparatus, the first and second directions are preferably substantially perpendicular to each other.

[0014] In the separating apparatus, the first direction is preferably a direction in which the major surface of the member is substantially horizontal.

[0015] In the separating apparatus, preferably, the member to be processed comprises a plate member, and the separation means cuts the plate member in a direction of plane to separate the member into two plate members.

[0016] In the separating apparatus, preferably, the second direction is a direction in which the major surface of the plate member is substantially vertical, and the separation means ejects the fluid toward the plate member in the vertical direction to separate the plate member into two plate members.

[0017] In the separating apparatus, the first direction is preferably a direction in which the major surface of the plate member is substantially horizontal.

[0018] In the separating apparatus, the manipulation means preferably comprises a pair of holding means for holding the plate member by sandwiching the member from two surface sides when the separation means separates the plate member.

[0019] In the separating apparatus, each of the holding means preferably comprises chuck means for chucking the plate member.

[0020] In the separating apparatus, preferably, the manipulation means comprises pivot means for pivoting at least one of the pair of holding means about a shaft parallel to a chuck surface of the chuck means, and the direction of the major surface of the plate member is changed by the pivot means.

[0021] In the separating apparatus, preferably, the manipulation means comprises pivot means for pivoting the pair of holding means about shafts parallel to chuck surfaces of the chuck means, and the direction of the major surface of the plate member is changed by the pivot means.

[0022] In the separating apparatus, the shaft as a pivot center of the holding means is preferably arranged at a position where the pair of holding means do not interfere with each other.

ferre with each other.

[0023] The separating apparatus preferably further comprises rotation means for rotating the member about a shaft perpendicular to the major surface.

[0024] In the separating apparatus, the rotation means preferably comprises means for rotating the member when the separation means separates the member.

[0025] In the separating apparatus, preferably, the separation means separates the member using a stream of a liquid, and the rotation means comprises means for rotating at least one of the members separated by the separation means to remove the liquid sticking to the member.

[0026] The separating apparatus preferably further comprises rotation means for rotating at least one of the pair of holding means about a shaft perpendicular to a holding surface.

[0027] In the separating apparatus, the rotation means preferably rotates the holding means when the separation mean separates the member.

[0028] In the separating apparatus, preferably, the separation means separates the member using a stream of a liquid, and the rotation means rotates the holding means to remove the liquid sticking to the member held by the holding means after the member is separated by the separation means.

[0029] The separating apparatus preferably further comprises a chamber for covering the apparatus.

[0030] In the separating apparatus, the chamber preferably has a shutter capable of opening/closing.

[0031] The separating apparatus preferably further comprises transfer means for transferring the member to be processed to the manipulation means and receiving the separated member from the manipulation means, the transfer means being arranged outside the chamber and transferring/receiving the member to/from the manipulation means while opening the shutter.

[0032] In the separating apparatus, the shutter is preferably closed at least when the member is separated by the separation means.

[0033] The separating apparatus preferably further comprises positioning means for positioning the member to be processed with respect to the manipulation means.

[0034] In the separating apparatus, preferably, the member to be separated has a fragile layer as a separation layer, and the fragile layer is substantially parallel to the major surface of the member.

[0035] According to the present invention, there is also provided a member processing apparatus characterized by comprising manipulation means for changing a direction of a major surface of a member, rotation means for rotating the member about a shaft perpendicular to the major surface, and processing means for processing the member while the rotation means is rotating the member, wherein the manipulation means receives the member with the major surface whose

direction matches with a first direction, matches the direction of the major surface with a second direction, and moves the member to a position where the processing means can process the member, and also matches the direction of the major surface of the member which has been processed by the processing means with the first direction.

[0036] In the processing apparatus, the first and second directions are preferably substantially perpendicular to each other.

[0037] In the processing apparatus, the first direction is preferably a direction in which the major surface of the member is substantially horizontal.

[0038] In the processing apparatus, preferably, the processing means processes the member using a liquid, and the rotation means rotates the member to remove the liquid sticking to the member after the member is processed by the processing means.

[0039] According to the present invention, there is also provided a processing apparatus characterized by comprising holding means for holding a member, manipulation means for changing a direction of a holding surface of the holding means, processing means for processing the member held by the holding means, and rotation means for rotating the holding means holding the member about a shaft perpendicular to the holding surface when the processing means is processing and/or has processed the member, wherein the manipulation means matches the direction of the holding surface with a first direction when the holding means is to receive the member to be processed, matches the direction of the holding surface of the holding means with a second direction after the holding means receives and holds the member, and moves the holding means to a position where the processing means can process the member, and also matches the direction of the holding surface of the holding means with the first direction after processing by the processing means is complete.

[0040] In the processing apparatus, the first and second directions are preferably substantially perpendicular to each other.

[0041] In the processing apparatus, the first direction is preferably a direction in which the major surface of the member is substantially horizontal.

[0042] In the processing apparatus, preferably, the processing means processes the member using a liquid, and the rotation means rotates the member to remove the liquid sticking to the member after the member is processed by the processing means.

[0043] According to the present invention, there is provided a member separating method characterized by comprising the reception step of receiving a member with a major surface whose direction matches with a first direction, the manipulation step of matching the direction of the major surface of the member with a second direction, and the separation step of separating the member using a stream of a fluid.

[0044] The separating method preferably further comprises the second manipulation step of matching a direction of a major surface of at least one member of the members separated in the separation step with the first direction.

[0045] The separating method preferably further comprises the second manipulation step of matching directions of major surfaces of the members separated in the separation step with the first direction.

[0046] In the separating method, the first and second directions are preferably substantially perpendicular to each other.

[0047] In the separating method, the first direction is preferably a direction in which the major surface of the member is substantially horizontal.

[0048] In the separating method, preferably, the member to be processed comprises a plate member, and the separation step comprises cutting the plate member in a direction of plane to separate the member into two plate members.

[0049] In the separating method, preferably, the second direction is a direction in which the major surface of the plate member is substantially vertical, and the separation step comprises ejecting the fluid toward the plate member in the vertical direction to separate the plate member into two plate members.

[0050] In the separating method, the first direction is preferably a direction in which the major surface of the plate member is substantially horizontal.

[0051] In the separating method, the separation step preferably comprises holding the plate member by sandwiching the member from two surface sides.

[0052] In the separating method, the separation step preferably comprises separating the member using the stream of a fluid while rotating the member to be processed about a shaft perpendicular to the major surface.

[0053] In the separating method, preferably, the separation step comprises separating the member using a liquid, and the method further comprises rotating at least one of the members separated to remove the liquid sticking to the member after the member is separated in the separation step.

[0054] In the separating method, the separation step is preferably executed in a chamber to prevent the fluid from scattering.

[0055] In the separating method, preferably, the member to be processed has a fragile layer as a separation layer, and the fragile layer is substantially parallel to the major surface of the member.

[0056] In the separating method, the fragile layer preferably comprises a porous layer.

[0057] In the separating method, the fragile layer preferably comprises a layer having microcavity.

[0058] In the separating method, preferably, the member to be processed is prepared by bonding at least two plate members, and at least one of the two plate members comprises a semiconductor substrate.

[0059] In the separating method, the semiconductor

substrate preferably comprises a single-crystal silicon substrate.

[0060] In the separating method, preferably, the member to be processed is prepared by bonding at least two plate members, and at least one of the two plate members comprises an insulating substrate.

[0061] In the separating method, the insulating substrate preferably comprises a quartz substrate.

[0062] In the separating method, preferably, the member to be processed is prepared by bonding at least two plate members, and at least one of the two plate members comprises a transparent substrate.

[0063] In the separating method, the member to be processed is preferably prepared by bonding a first substrate sequentially having a nonporous layer and a porous layer inward from a surface to a second substrate via the nonporous layer.

[0064] In the separating method, the nonporous layer preferably has a single-crystal silicon layer.

[0065] In the separating method, the nonporous layer preferably has an insulating layer on the single-crystal silicon layer.

[0066] In the separating method, the insulating layer is preferably formed from a silicon oxide.

[0067] In the separating method, the second substrate preferably comprises an insulating substrate.

[0068] In the separating method, the second substrate preferably comprises a transparent substrate.

[0069] In the separating method, the second substrate preferably comprises a quartz substrate.

[0070] In the separating method, the porous layer is preferably formed by anodizing a single-crystal silicon substrate.

[0071] In the separating method, the member to be processed is preferably prepared by bonding a second substrate to a surface of a first substrate incorporating a microcavity layer.

[0072] In the separating method, the microcavity layer is preferably formed by implanting ions into a single-crystal silicon substrate.

[0073] In the separating method, water is preferably used as the fluid.

[0074] According to the present invention, there is provided a semiconductor substrate manufacturing method characterized by comprising the steps of preparing a first substrate incorporating a porous layer or a microcavity layer, bonding the first substrate to a second substrate to prepare a bonded substrate stack, separating the bonded substrate stack into a first substrate side and a second substrate side using the porous layer or microcavity layer as a separation region by using any one of the above separating methods, and removing the porous layer or microcavity layer remaining on the second substrate side.

[0075] The semiconductor substrate manufacturing method preferably further comprises the step of, after the bonded substrate stack is separated, removing the porous layer or microcavity layer remaining on the first

substrate side to reuse the first substrate.

[0076] In the semiconductor substrate manufacturing method, the porous layer is preferably formed by anodizing a semiconductor substrate.

[0077] In the semiconductor substrate manufacturing method, the microcavity layer is preferably formed by implanting ions in a semiconductor substrate.

[0078] Further objects, features and advantages of the present invention will become apparent from the following detailed description of the embodiments of the present invention with reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0079]

Figs. 1A to 1E are views for explaining steps in manufacturing an SOI substrate according to a preferred embodiment of the present invention;

Figs. 2A to 2C are views showing the principle of a separating apparatus according to a preferred embodiment of the present invention;

Fig. 3 is a schematic view showing the first arrangement of a separating apparatus;

Fig. 4 is a schematic view showing the first arrangement of the separating apparatus;

Fig. 5 is a schematic view showing the first arrangement of the separating apparatus;

Fig. 6 is a schematic view showing the first arrangement of the separating apparatus;

Fig. 7 is a schematic view showing the first arrangement of the separating apparatus;

Fig. 8 is a view showing the first arrangement of an adjustment mechanism for adjusting the clearance between substrate holding portions;

Fig. 9 is a view showing the second arrangement of an adjustment mechanism for adjusting the clearance between substrate holding portions;

Fig. 10 is a schematic view showing the second arrangement of an automatic separating apparatus;

Fig. 11 is a schematic view showing the second arrangement of the automatic separating apparatus;

Fig. 12 is a schematic view showing the second arrangement of the automatic separating apparatus; and

Fig. 13 is a schematic view showing the second arrangement of the automatic separating apparatus.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0080] A preferred embodiment of the present invention will be described below with reference to the accompanying drawings.

[0081] Figs. 1A to 1E are views for explaining steps in

manufacturing an SOI substrate according to a preferred embodiment of the present invention.

[0082] In the step shown in Fig. 1A, a single-crystal Si substrate 11 is prepared, and a porous Si layer 12 is formed on the substrate surface by anodizing or the like. In the step shown in Fig. 1B, a nonporous single-crystal Si layer 13 is formed on the porous Si layer 12 by epitaxial growth. After this, the surface is oxidized to form an SiO<sub>2</sub> layer 15. With this process, a first substrate 10 is formed.

[0083] In the step shown in Fig. 1C, a second substrate 20 consisting of single-crystal Si is prepared. The first and second substrates 10 and 20 are brought into contact with each other at room temperature such that the second substrate 20 opposes an insulating layer 15. After this, the first and second substrates 10 and 20 are bonded by anodic bonding, pressing, heating, or a combination thereof. The insulating layer 15 may be formed on the nonporous single-crystal Si layer 13, as described above, on the second substrate 20, or on both of them as far as the state shown in Fig. 1C is obtained when the first and second substrates are brought into contact with each other.

[0084] In the step shown in Fig. 1D, the two substrates bonded to each other are separated at the porous Si layer 12. Consequently, a multilayered structure of a porous Si layer 12', single-crystal Si layer 13, insulating layer 15, and the single-crystal Si substrate 20 is formed on the second substrate side (10' + 20). On the first substrate side (10'), a porous layer 12' is formed on the single-crystal Si substrate 11.

[0085] After separation, the porous Si layer 12' left on the first substrate is removed, and the substrate surface is planarized as needed, thereby reusing the first substrate as the single-crystal Si substrate 11 for forming the first substrate 10.

[0086] After the bonded substrates are separated, in the step shown in Fig. 1E, the porous layer 12" on the surface on the second substrate side (10' + 20) is selectively removed. With this process, a multilayered structure of the single-crystal Si layer 13, insulating layer 15, and single-crystal Si substrate 20, i.e., a substrate having an SOI structure is obtained.

[0087] As the second substrate, not only the single-crystal Si substrate but also an insulating substrate (e.g., a quartz substrate) or a transparent substrate (e.g., a quartz substrate) can be used.

[0088] In this embodiment, to facilitate the process of bonding two substrates and then separating them, the porous layer 12 having a fragile structure is formed in the separation region. Instead of the porous layer, for example, a microcavity layer may be formed. A microcavity layer can be formed by implanting ions into a semiconductor substrate.

[0089] In this embodiment, in the step shown in Fig. 1D, i.e., in the process of separating a substrate (to be referred to as a bonded substrate stack hereinafter) prepared by bonding two substrates, a high-pressure liquid

or gas (fluid) is injected toward the separation region of the bonded substrate stack to break the porous layer, thereby separating the bonded substrate stack into two substrates.

#### [Principle of Separating Apparatus]

[0090] The principle of a separating apparatus according to a preferred embodiment of the present invention will be described first. The separating apparatus of this embodiment uses a water jet method. Generally, the water jet method ejects high-speed, high-pressure stream of water to an object to, e.g., process, remove a coating film from the surface, or clean the surface ("Water Jet", Vol. 1, No. 1, page 4 (1984)).

[0091] This separating apparatus ejects a high-speed, high-pressure stream of a liquid or gas (fluid) to the porous layer (separation region) of a bonded substrate stack in the direction of substrate surface to selectively break the porous layer, thereby separating the substrate stack at the porous layer. The stream will be referred to as a "jet" hereinafter. The liquid or gas (fluid) forming a jet will be referred to as a "jet medium". As the jet medium, it is possible to use water, an organic solvent such as alcohol, an acid such as hydrofluoric acid or nitric acid, an alkali such as potassium hydroxide, other alkalis, a gas such as air, nitrogen gas, carbonic acid gas, rare gas, or an etching gas or other gases.

[0092] Figs. 2A to 2C are views showing the principle of the separating apparatus of the preferred embodiment of the present invention. This separating apparatus has a pair of substrate holding portions 22 and 23 for supporting a substrate. Rotary shafts 24 and 25 are coupled to the substrate holding portions 22 and 23, respectively. The substrate holding portions 22 and 23 are supported to freely pivot about rotary shafts 26 and 27, respectively.

[0093] To separate a bonded substrate stack 21 into two substrates 21a and 21c, first, the substrate support surfaces of the substrate holding portions 22 and 23 are made horizontal, as shown in Fig. 2A. The bonded substrate stack 21 is mounted at a predetermined position on the substrate holding portion 22 and chucked on the substrate support surface.

[0094] Next, as shown in Fig. 2B, the substrate holding portions 22 and 23 are pivoted about the rotary shafts 26 and 27, respectively, to oppose them each other, so the bonded substrate stack 21 is sandwiched and held by the substrate holding portions 22 and 23. At this time, the substrate support surfaces of the substrate holding portions 22 and 23 are vertical.

[0095] In this state, a jet medium (e.g., water) 29 is ejected from an ejection nozzle 28 and injected into the separation region (porous region) of the bonded substrate stack 21 while the bonded substrate stack 21 is rotated about the rotary shafts 24 and 25. With this operation, the bonded substrate stack 21 is separated into the two substrates 21a and 21c. During this sepa-

rating, the bonded substrate stack 21 can be held without vacuum chuck.

[0096] As shown in Fig. 2C, the substrate holding portions 22 and 23 are pivoted about the rotary shafts 26 and 27, respectively, until the substrate support surfaces become horizontal. During this operation, the substrate 21a is chucked by the substrate holding portion 22, and the substrate 21c is chucked by the substrate holding portion 23.

[0097] Then a liquid such as water is used as the jet medium, the separated substrates 21a and 21c can be dried by rotating the substrate holding portions 22 and 23 about the rotary shafts 24 and 25 at a high speed, respectively.

[0098] In the state shown in Fig. 2B, i.e., when the bonded substrate stack is sandwiched by the substrate holding portions 22 and 23, the rotary shafts 26 and 27 must be outside a space (projection space) 30 formed by projecting the surface of the bonded substrate stack 21 in the axial direction to prevent interference between the substrate holding portions 22 and 23. However, if a mechanism for moving one or both of the substrate holding portions 22 and 23 in the horizontal direction is arranged, the substrate holding portions 22 and 23 can be placed in the projection space 30.

[0099] With the above-described separating apparatus, the bonded substrate stack 21 can be transferred to the separating apparatus in the horizontal state, and the separated substrates 21a and 21c can be received from the separating apparatus in the horizontal state. In the arrangement which allows substrate transfer in the horizontal state, the substrates can be supported from the lower side. Hence, risks of substrate drop during conveyance or transfer are decreased.

[0100] Specific arrangements of the separating apparatus of the preferred embodiment of the present invention will be described below.

#### [First Arrangement of Separating Apparatus]

[0101] Figs. 3 to 7 are schematic views showing the first arrangement of a separating apparatus. A separating apparatus 100 comprises a pair of substrate manipulation portions 150 and 160 for manipulating substrates.

[0102] The substrate manipulation portions 150 and 160 have substrate holding portions 108 and 109 for supporting substrates, respectively. The substrate holding portions 108 and 109 have vacuum chuck grooves 108a and 109a as a mechanism for chucking the substrate. The chucks 108a and 109a communicate with vacuum lines extending through rotary shafts 106 and 107, respectively. The vacuum lines are connected to an external vacuum line through a rotary vacuum joint.

[0103] A bonded substrate stack 101 to be processed incorporates a porous layer 101b as a fragile structure portion and is separated into two substrates 101a and 101c at the porous layer 101b.

[0104] To separate the bonded substrate stack 101, the bonded substrate stack 101 is sandwiched and supported vertically by the substrate holding portions 108 and 109, as shown in Fig. 5.

[0105] In this separating apparatus 100, for example, the bonded substrate stack is set such that the substrate 101a is present on the first substrate side (10'), and the substrate 101c is present on the second substrate side (10' + 20) in Fig. 1D.

[0106] The substrate holding portion 108 is coupled to one end of the rotary shaft 106 axially and rotatably supported by a shaft support portion 102 through a bearing 104. The other end of the rotary shaft 106 is coupled to a driving source 114. As the driving source 114, for example, a motor is suitable. In separation processing, the bonded substrate stack 101 is rotated by a rotational force transmitted from the driving source 114. The driving source 114 rotates the rotary shaft 106 at a rotation rate designated in accordance with an instruction from a controller (not shown).

[0107] On the other hand, the substrate holding portions 109 is coupled to one end of the rotary shaft 107 axially and rotatably supported by the shaft support portion 103 through a bearing 105. The other end of the rotary shaft 107 is coupled to a driving source 115. As the driving source 115, for example, a motor is suitable. In separation processing, the bonded substrate stack 101 is rotated by a rotational force transmitted from the driving source 115. The driving source 115 rotates the rotary shaft 107 in synchronism with rotation of the rotary shaft 106 in accordance with an instruction from the controller (not shown). The rotary shafts 106 and 107 are rotated in synchronism with each other to prevent twist of the bonded substrate stack 101.

[0108] Independent driving sources may be coupled to the rotary shafts 106 and 107, respectively, as described above. However, using a single driving source, the rotational force generated by the driving source may be distributed to the rotary shafts 106 and 107. In this case, the rotary shafts 106 and 107 can easily be rotated in synchronism with each other.

[0109] Alternatively, only one of the rotary shafts 106 and 107 may be driven. For example, when only the driving source 114 for driving the rotary shaft 106 is arranged, the rotary shaft 106, substrate holding portion 108, bonded substrate stack 101, substrate holding portion 109, and rotary shaft 107 integrally rotate before separation of the bonded substrate stack 101. When the bonded substrate stack 101 is separated into two substrates, the members on the rotary shaft 107 side stop.

[0110] The shaft support portion 103 on the rotary shaft 107 side incorporates a spring 111 for pressing the bonded substrate stack 101. Hence, the bonded substrate stack 101 receives a force in a direction in which the substrate 101a is pressed against the substrate 101c (negative direction of the X-axis). As a result, after the bonded substrate stack 101 is separated into the two substrates 101a and 101c by a jet

from an ejection nozzle 110, and even when the two substrates 101a and 101c are not vacuum-chucked by the substrate holding portions 109 and 108, respectively, the substrates 101a and 101c do not drop.

[0111] In this embodiment, the spring 111 applies a force in the direction in which the substrate 101a is pressed against the substrate 101c (negative direction of the X-axis). However, the force may be applied in a direction in which the substrate 101a is separated from the substrate 101c by changing the position of the spring. In this case, when the bonded substrate stack 101 is physically separated into the two substrates 101a and 101c by a jet from the ejection nozzle 110, the substrate 101a is separated from the substrate 101c.

[0112] The separating apparatus 100 has an adjustment mechanism for adjusting the clearance between the substrate holding portions 108 and 109. Specific examples of the adjustment mechanism will be described below.

[0113] Fig. 8 is a view showing the first arrangement of the adjustment mechanism. The adjustment mechanism shown in Fig. 8 uses an air cylinder 122. The air cylinder 122 is fixed to the shaft support portion 103. When a piston rod 121 is retracted (driven), the driving source (e.g., motor) 115 is pulled. When drive of the piston rod 121 is canceled, the force of the spring 111 can be made to act on the rotary shaft 107 to press the substrate.

[0114] Fig. 9 is a view showing the second arrangement of the adjustment mechanism. The adjustment mechanism shown in Fig. 9 uses an eccentric cam 131 and a motor. The eccentric cam 131 is coupled to a motor (not shown). The clearance between the substrate holding portions 108 and 109 is adjusted by moving a driving plate 132 coupled to the rear end of the driving source 115. The force of the spring 111 acts on the rotary shaft 107 in the direction in which the substrate is pressed. To hold the bonded substrate stack 101 and separate it into two substrates, the eccentric cam 131 is pivoted in a direction in which restriction of the driving plate 132 by the eccentric cam 131 is canceled, i.e., in a direction in which a gap is formed between the eccentric cam 131 and driving plate 132. With this operation, the pressing force of the spring 111 can be made to act on the bonded substrate stack 101.

[0115] Even when a spring acting in a direction in which the bonded substrate stack 101 is pulled is arranged in place of the spring 111, an adjustment mechanism for adjusting the clearance between the substrate holding portions 108 and 109 is necessary. In this case, the adjustment mechanism is used to push the substrate holding portion 109 until it comes in contact with the bonded substrate stack 101 to chuck the bonded substrate stack 101 on the substrate support surface of the substrate holding portion 109.

[0116] The separating apparatus 100 has driving sources (e.g., motors) 151 and 161 for rotating rotary shafts 112 and 113 to pivot the substrate manipulation

portions 150 and 160, respectively. The driving sources 151 and 161 are fixed to, e.g., the main body frame of the separating apparatus 100.

[0117] As shown in Fig. 3, in the separating apparatus 100, the substrate manipulation portions 150 and 160 can be pivoted about the rotary shafts 112 and 113 by the driving sources 151 and 161 to make the substrate support surfaces of the substrate holding portions 108 and 109 horizontal or vertical, respectively.

[0118] Instead of preparing two driving sources for the substrate manipulation portions 150 and 160, respectively, a single driving source may be arranged. In this case, the output from the driving source is distributed to drive the substrate manipulation portions 150 and 160.

[0119] In the separating apparatus 100, the rotary shafts 112 and 113 are placed outside the space (projection space) formed by projecting the bonded substrate stack 101 in the axial direction when the bonded substrate stack 101 is sandwiched (supported vertically) by the substrate holding portions 108 and 109. In addition, the rotary shafts 112 and 113 are arranged in a direction parallel to the substrate support surfaces of the substrate holding portions 108 and 109 (Y-axis direction). Hence, the substrate manipulation portions 150 and 160 operate without interfering each other, and the bonded substrate stack 101 does not damage the separated substrates 101a and 101c.

[0120] Even when the rotary shafts 112 and 113 are placed in the projection space, interference between the substrate manipulation portions 150 and 160 can be avoided by increasing the retreat distance of the substrate holding portion 109 to the shaft support portion 103 side.

[0121] A series of procedures of bonded substrate stack separation processing by the separating apparatus 100 will be described below.

[0122] First, as shown in Fig. 3, the substrate manipulation portions 150 and 160 are driven by the driving sources 151 and 161 to make the substrate support surfaces of the substrate holding portions 108 and 109 horizontal, respectively. The substrate holding portion 109 is retracted into the shaft support portion 103 by the adjustment mechanism shown in Fig. 8 or 9, as shown in Fig. 3. In this state, the bonded substrate stack 101 is mounted on the substrate holding portion 108, and the pressure in the grooves 108a is reduced to chuck the bonded substrate stack 101 on the substrate support surface. The bonded substrate stack 101 is preferably mounted on the substrate holding portion 108 such that the center of the bonded substrate stack matches with the center of the substrate holding portion 108.

[0123] Next, as shown in Fig. 4, the substrate manipulation portions 150 and 160 are pivoted by the driving sources 151 and 161 to make the substrate support surfaces of the substrate holding portions 108 and 109 vertical, respectively.

[0124] As shown in Fig. 5, the substrate holding portion 109 is pushed from the shaft support portion 103 by



the action of the spring 111, so the bonded substrate stack 101 is pressed by the substrate holding portion 109. When the arrangement shown in Fig. 8 or 9 is employed, this operation can be realized by canceling restriction of the rotary shaft 107 by the air cylinder 122 or eccentric cam 131.

[0125] In this state, the bonded substrate stack 101 may be vacuum-chucked by one or both of the substrate holding portions 108 and 109. When the pressing force of the spring 111 suffices, the bonded substrate stack 101 can be held by only the pressing force without vacuum chuck.

[0126] Next, the driving sources 114 and 115 are operated in synchronism to rotate the bonded substrate stack 101. A jet medium (e.g., water) is compressed and supplied to the ejection nozzle 110 by a high-pressure pump (not shown) to inject the jet into the porous layer 101b as the separation region of the bonded substrate stack 101, i.e., in the vertical direction. When the jet is injected while rotating the bonded substrate stack 101, the bonded substrate stack 101 is separated into the two substrates 101a and 101c.

[0127] After the bonded substrate stack 101 is physically separated into the two substrates, the substrate holding portions 108 and 109 is retreated to the shaft support portion 103 side by the adjustment mechanism shown in Fig. 8 or 9, as shown in Fig. 6. With this operation, the two substrates 101a and 101c which are physically separated are separated spatially. When the substrates 101a and 101c are not chucked by the substrate holding portions 109 and 108, respectively, in separating the bonded substrate stack 101, the substrates 101a and 101c need be chucked by the substrate holding portions 109 and 108, respectively, before the substrate holding portion 109 is retreated to the shaft support portion 103 side.

[0128] As shown in Fig. 7, the substrate manipulation portions 150 and 160 are pivoted about the rotary shafts 112 and 113 by the driving sources 151 and 161 to make the substrate support surfaces of the substrate holding portions 108 and 109 horizontal, respectively. The substrates 101a and 101c are held horizontally.

[0129] When separation processing has been executed using a liquid as a jet medium, the jet medium remains on the separated substrates 101a and 101c. The jet medium sticking to the substrates 101a and 101c is preferably removed by rotating the substrate holding portions 108 and 109 by the driving sources 114 and 115, respectively, to dry the substrates (spin drying). For spin drying, a shielding plate for shielding the scattering jet medium is preferably inserted between the two substrate manipulation portions 150 and 160.

[0130] The substrates 101a and 101c may be transferred to another drying apparatus to dry them by the apparatus. When one of the substrates is to be discarded, the substrate to be discarded need not always be dried.

[0131] As described above, the separating apparatus

100 executes separation processing while holding the bonded substrate stack vertically. One reason for this is that when the jet is not ejected in the vertical direction, the jet orbit is bent downward by gravitation, and it becomes difficult to inject the jet to the desired position (separation region) of the bonded substrate stack. Another reason is that when the separation surface (porous layer) of the bonded substrate stack is parallel to the direction of jet, the jet can efficiently act on the separation surface, so the efficiency of separation processing can be increased.

[0132] According to the separating apparatus 100 having the substrate manipulation portions 150 and 160, separation processing can be executed while holding the bonded substrate stack 101 vertically, and additionally, the bonded substrate stack can be transferred to the separating apparatus in the horizontal state, and the separated substrates can also be received in the horizontal state. Since the substrates can be supported from the lower side during substrate transfer, risks of substrate drop can be decreased. On the other hand, if a mechanism for transferring the bonded substrate stack to the separating apparatus in the vertical state or a mechanism for receiving the separated substrates in the vertical state is employed, the substrates may drop.

[0133] In addition, according to this separating apparatus, when the substrate support surfaces of the substrate holding portions 108 and 109 are set horizontally, a wide space can be ensured on the substrate support surfaces. This facilitates substrate transfer or reception.

#### [Second Arrangement of Separating Apparatus]

[0134] This embodiment is related to an automatic separating apparatus incorporating the separating apparatus 100 of the first arrangement, which automatically executes a series of operations of extracting a bonded substrate stack stored in a cassette, transferring it to the separating apparatus 100, separating a bonded substrate stack 101 in the separating apparatus 100, and storing the separated substrates in another cassette.

[0135] Figs. 10 to 13 are schematic views showing the second arrangement of the automatic separating apparatus. More specifically, Fig. 10 is a plan view schematically showing a state wherein the bonded substrate stack 101 is set in the separating apparatus 100, Fig. 11 is a view of the arrangement shown in Fig. 10 when viewed from one side, Fig. 12 is a plan view schematically showing a state wherein the bonded substrate stack is to be separated, and Fig. 13 is a view of the arrangement shown in Fig. 12 when viewed from one side.

[0136] The automatic separating apparatus of this embodiment comprises the separating apparatus 100 of the first arrangement, and a transfer apparatus 500 for transferring a bonded substrate stack and separated substrates.

[0137] Preferably, the separating apparatus 100 is set in a chamber 400, and a shutter 503 is arranged between the chamber 400 and transfer apparatus 500. Preferably, the shutter 503 is opened when the bonded substrate stack 101 is to be set in the separating apparatus 100 or separated substrates are to be extracted, and closed during separation processing. With this arrangement, a jet medium (e.g., water) can be prevented from scattering from the chamber 400 during separation processing.

[0138] The transfer apparatus 500 comprises a transfer robot 501 for transferring the bonded substrate stack 101 and separated substrates, and a positioning unit 507 for positioning the bonded substrate stack 101 with respect to a substrate holding portion 108.

[0139] To execute separation processing, a cassette 504 storing one or a plurality of bonded substrate stacks 101 and empty cassettes 505 and 506 for storing separated substrates 101a and 101c are set at predetermined positions in the transfer apparatus 500. The cassette 504 is set such that the bonded substrate stacks are held horizontally and the opening portion faces the transfer robot 501. The cassettes 505 and 506 are set such that the separated substrates can be stored in the horizontal state and their opening portions face the transfer robot 501.

[0140] The procedure of separation processing by the automatic separating apparatus will be described below.

[0141] The operator sets the cassette 504 storing the bonded substrate stacks 101 and the empty cassettes 505 and 506 at predetermined positions in the transfer apparatus 500. When the operator instructs to start separation processing through a control panel (not shown), the automatic separating apparatus starts the following series of processing operations.

[0142] First, the separating apparatus 100 pivots substrate manipulation portions 150 and 160 to make the substrate support surfaces horizontal, as shown in Figs. 10 and 11.

[0143] The transfer robot 501 inserts a robot hand 502 having a chuck mechanism under a corresponding bonded substrate stack 101 in the cassette 504, chucks the lower surface of the bonded substrate stack, and removes the bonded substrate stack 101.

[0144] The transfer robot 501 mounts the chucked bonded substrate stack 101 on the support table of the positioning unit 507 and cancel chuck. The positioning unit 507 aligns the central position of the bonded substrate stack 101 to the reference position by two guide members opposing each other. The transfer robot 501 chucks the lower surface of the bonded substrate stack 101 on the support table of the positioning unit 507, extends the robot hand 502 toward the substrate holding portion 108 of the separating apparatus 100, and sets the bonded substrate stack 101 at a predetermined position on the substrate holding portion 108. By using the positioning unit 507, the bonded substrate stack 101

can be positioned with respect to the substrate holding portion 108.

[0145] When the transfer robot 501 is to set the bonded substrate stack 101 on the substrate holding portion 108, the shutter 503 is open.

[0146] Each bonded substrate stack 101 can be set at a correct position on the substrate holding portion 108 by positioning each bonded substrate stack 101 by the positioning unit 507. Since the center of the bonded substrate stack 101 can be matched with the central axis of a rotary shaft 106, the distance between an ejection nozzle 110 and the side surface of the bonded substrate stack 101 is kept unchanged while the bonded substrate stack 101 is rotated and separated. Hence, the jet can be made to uniformly act along the entire circumference of the bonded substrate stack 101.

[0147] When setting of the bonded substrate stack 101 on the substrate holding portion 108 is complete, the transfer robot 501 retracts the robot hand 502, and then, the shutter 503 is closed.

[0148] In the separating apparatus 100, the substrate manipulation portions 150 and 160 are pivoted by driving sources 151 and 161 to make the bonded substrate stack 101 vertical, respectively, and the bonded substrate stack 101 is sandwiched and vacuum-chucked by the substrate holding portions 108 and 109.

[0149] The separating apparatus 100 executes separation processing. More specifically, in the separating apparatus 100, the bonded substrate stack 101 is rotated by driving sources 114 and 115', and simultaneously, a jet is ejected and injected from the ejection nozzle 110 into the separation region (porous region 101b) of the bonded substrate stack 101. With this separation processing, the bonded substrate stack 101 is separated into the two substrates 101a and 101c. The driving source 115' includes not only the above-described driving source 115 but also the adjustment mechanism shown in Fig. 8 or 9.

[0150] When the bonded substrate stack 101 is separated into the two substrates 101a and 101c, the separating apparatus 100 separates the two substrates 101a and 101c by the above-described adjustment mechanism. After this, the substrate manipulation portions 150 and 160 are pivoted by the driving sources 151 and 161 to make the substrate support surfaces of the substrate holding portions 108 and 109 horizontal, respectively.

[0151] By rotating the substrate holding portions 108 and 109 at the driving sources 114 and 115' at a high speed, the jet medium sticking to the separated substrates is removed (spin drying).

[0152] Subsequently, the shutter 503 is opened. The transfer robot 501 extends the robot hand 502 under the substrate 101c on the substrate holding portion 108, holding the substrate 101c by chucking its lower surface, and stores the substrate 101c in the cassette 505. In the same way, the transfer robot 501 extends the robot hand 502 under the substrate 101a on the substrate holding portion 109, holds the substrate 101a by

chucking its lower surface, and stores the substrate 101a in the cassette 506.

[0153] With the above processing, separation processing of one bonded substrate stack is ended. This automatic separating apparatus can separate all bonded substrate stacks in the cassette 504 by repeating the above processing for all unprocessed bonded substrate stacks.

[0154] According to this automatic separating apparatus, when the cassette storing bonded substrate stacks and two empty cassettes are prepared and set in the transfer apparatus 500, and execution of separation processing is instructed, separation processing is automatically executed, and two substrates which are separated and dried are selectively stored in the two restoration cassettes.

[0155] As described above, even when separation processing is automatically executed, the arrangement capable of transferring substrates between the transfer apparatus and separating apparatus in the horizontal state has a remarkable advantage.

[0156] This advantage is easy to understand in comparison with an arrangement for transferring substrates between the transfer apparatus and separating apparatus in the vertical state. In this case, the substrate holding portion can hardly reliably chuck the bonded substrate stack unless the transfer robot transfers the substrate to the substrate holding portion while accurately holding it vertically, and the bonded substrate stack may sometimes drop. This also applies to reception of separated substrates by the transfer robot. If the substrate holding surface of the robot hand is not accurately parallel to the substrate, the robot hand can hardly reliably chuck the substrate.

#### [Application Example of Separating Apparatus]

[0157] As an application example of the above separating apparatus, a method of manufacturing an SOI substrate will be described below with reference to Figs. 1A to 1E.

[0158] As a single-crystal Si substrate 11, a p- or n-type (100) single-crystal Si substrate having a thickness of 625 [ $\mu\text{m}$ ], a diameter of 5 [inch], and a resistivity of 0.01 [ $\Omega \cdot \text{cm}$ ] was prepared. This single-crystal Si substrate 11 was dipped in an HF solution and anodized to form a porous Si layer 12 having a thickness of 12 [ $\mu\text{m}$ ] (Fig. 1A). The anodizing conditions are as follows.

Current density : 7 [mA/cm<sup>2</sup>]  
Anodizing solution : HF : H<sub>2</sub>O : C<sub>2</sub>H<sub>5</sub>OH = 1 : 1 : 1  
Process time : 11 [min]

[0159] This substrate was heated to 400 [°C] in an oxygen atmosphere and oxidized for 1 hr. With this process, inner walls of pores in the porous Si layer 12 were covered with thermal oxide films. Subsequently, a single-crystal Si layer 13 having a thickness of 0.3  $\mu\text{m}$

was epitaxially grown on the porous Si layer 12 by CVD. The epitaxial growth conditions are as follows. Before this process, the substrate may be baked in a hydrogen atmosphere in the epitaxial furnace.

Source gas : SiH<sub>4</sub>  
Carrier gas : H<sub>2</sub>  
Temperature : 850 [°C]  
Pressure :  $1 \times 10^{-2}$  [Torr]  
Growth rate : 3.3 [nm/sec]

[0160] A 0.2- $\mu\text{m}$  thick SiO<sub>2</sub> layer 15 was formed on the single-crystal Si layer (epitaxial Si layer) 13 (Fig. 1B). A single-crystal Si substrate 20 was separately prepared. The surface of the SiO<sub>2</sub> layer 15 and single-crystal Si substrate 20 were brought into contact with each other at room temperature. After this, a heat treatment was performed at a temperature of 1,100 [°C] for 1 hr to bond the two substrates (Fig. 1C).

[0161] This bonded substrate stack was stored in the cassette 504 and set in the transfer apparatus 500 of the automatic separating apparatus of the second arrangement, and separation processing was executed (Fig. 1D). As a jet medium, pure water was used. The jet diameter was set to be 0.2 [mm], and the pressure of water to be ejected was set to be 350 [Kg/cm<sup>2</sup>]. Separation processing was performed while fixing the position of the ejection nozzle immediately above the bonding interface. The bonded substrate stack was rotated at a speed of about 8 [rpm].

[0162] Most bonded substrate stacks are completely separated when they have made about five revolutions. However, in consideration of variations between substrates, the automatic separating apparatus was set to inject the jet while rotating the bonded substrate stack for about 2 min.

[0163] Even after the bonded substrate stack was separated into two substrates, the two substrates were still in contact with each other due to the action of the spring 111. After a predetermined time had elapsed from the start of bonded substrate separation processing, one substrate holding portion 109 retreated to the shaft support portion 103 side to spatially separate the two substrates which had been physically separated. The substrates had no flaws, cracks, or damages.

[0164] The substrate (10" + 20) separated and stored in the cassette 505 was removed, and the porous Si layer on the surface was selectively etched using an HF/H<sub>2</sub>O<sub>2</sub>/H<sub>2</sub>O-based etchant. Since the etching rate for single-crystal Si was very low, the etching amount of the single-crystal Si substrate as the underlying layer of the porous Si layer could be neglected for practical use. With this etching process, an SOI substrate having the about 0.2- $\mu\text{m}$  thick single-crystal Si layer 13 on the SiO<sub>2</sub> film 15 could be formed (Fig. 1E).

[0165] It was confirmed that the surface of the resultant SOI substrate, i.e., the surface of the single-crystal

Si layer 13 had no defects. Observation of the section of the single-crystal Si layer 13 with a transmission electron microscope revealed that crystal defects and the like did not increase in the process after epitaxial growth, and satisfactory crystallinity was maintained.

[0166] Instead of forming an SiO<sub>2</sub> film on the surface on the single-crystal Si layer (epitaxial layer) 13 side, even when 1) an SiO<sub>2</sub> film was formed not on the surface on the single-crystal Si layer 13 side but on the side of an independently prepared single-crystal Si substrate, or 2) SiO<sub>2</sub> films were formed both on the surface on the single-crystal Si layer 13 side and on the side of a separately prepared single-crystal Si substrate, a satisfactory SOI substrate could be formed.

[0167] The substrate (single-crystal Si substrate 11) on which the porous Si layer was formed could be used as the first or second substrate again by removing the porous Si layer on the surface and planarizing the surface.

[0168] The substrate separating apparatus and method suitable to manufacture an SOI substrate have been described above as the preferred embodiments of the present invention. The separating apparatus and method of the present invention can also be used to separate or cut any other member. The member to be separated preferably as a fragile separation region such as a porous layer.

[0169] According to the present invention, for example, risks of drop of a member such as a substrate can be decreased.

[0170] The present invention is not limited to the above embodiments and various changes and modifications can be made within the spirit and scope of the present invention. Therefore, to apprise the public of the scope of the present invention, the following claims are made.

#### Claims

1. A separating apparatus for separating a member (101), characterized by comprising:

manipulation means (150, 160) for changing a direction of a major surface of the member (101); and

separation means (110) for separating the member using a stream of a fluid, wherein said manipulation means (150, 160) has a function of manipulating the member (101) to match the direction of the major surface with a first direction and a function of manipulating the member to match the direction of the major surface with a second direction.

2. The apparatus according to claim 1, characterized in that said manipulation means (150, 160) receives the member (101) with the major surface whose

direction matches with the first direction, matches the direction of the major surface with the second direction, and moves the member (101) to a position where said separation means (110) can process the member, and also matches a direction of a major surface of at least one member (101a, 101c) of the members (101) separated by said separation means (110) with the first direction.

3. The apparatus according to claim 1, characterized in that said manipulation means (150, 160) receives the member (101) with the major surface whose direction matches with the first direction, matches the direction of the major surface with the second direction, and moves the member (101) to a position where said separation means (110) can process the member, and also matches directions of major surfaces of members (101a, 101c) of the members (101) separated by said separation means (110) with the first direction.

4. The apparatus according to any one of claims 1 to 3, characterized in that the first and second directions are substantially perpendicular to each other.

5. The apparatus according to any one of claims 1 to 4, characterized in that the first direction is a direction in which the major surface of the member is substantially horizontal.

6. The apparatus according to any one of claims 1 to 4, characterized in that the member (101) to be processed comprises a plate member, and said separation means (110) cuts the plate member (101) in a direction of plane to separate the member into two plate members (101a, 101c).

7. The apparatus according to claim 6, characterized in that the second direction is a direction in which the major surface of the plate member is substantially vertical, and said separation means (110) ejects the fluid toward the plate member (101) in the vertical direction to separate the plate member (101) into two plate members (101a, 101c).

8. The apparatus according to claim 7, characterized in that the first direction is a direction in which the major surface of the plate member (101) is substantially horizontal.

9. The apparatus according to any one of claims 6 to 8, characterized in that said manipulation means (150, 160) comprises a pair of holding means (108, 109) for holding the plate member (101) by sandwiching the member from two surface sides when said separation means (110) separates the plate member (101).

10. The apparatus according to claim 9, characterized in that each of said holding means (108, 109) comprises chuck means (108a, 109a) for chucking the plate member (101).
11. The apparatus according to claim 10, characterized in that said manipulation means (150, 160) comprises pivot means (151, 161) for pivoting at least one of said pair of holding means (108, 109) about a shaft (112, 113) parallel to a chuck surface of said chuck means (108a, 109a), and the direction of the major surface of the plate member (101) is changed by said pivot means (151, 161).
12. The apparatus according to claim 10, characterized in that said manipulation means (150, 160) comprises pivot means (151, 161) for pivoting said pair of holding means (108, 109) about shafts (112, 113) parallel to chuck surfaces of said chuck means (108a, 109a), and the direction of the major surface of the plate member (101) is changed by said pivot means (151, 161).
13. The apparatus according to claim 11 or 12, characterized in that the shaft (112, 113) as a pivot center of said holding means (108, 109) is arranged at a position where said pair of holding means (108, 109) do not interfere with each other.
14. The apparatus according to any one of claims 1 to 13, characterized by further comprising rotation means (114, 115) for rotating the member (101) about a shaft (106, 107) perpendicular to the major surface.
15. The apparatus according to claim 14, characterized in that said rotation means (114, 115) comprises means for rotating the member (101) when said separation means (110) separates the member (101).
16. The apparatus according to claim 14 or 15, characterized in that said separation means (110) separates the member (101) using a stream of a liquid, and said rotation means (114, 115) comprises means for rotating at least one of the members (101a, 101c) separated by said separation means (110) to remove the liquid sticking to the member.
17. The apparatus according to any one of claims 9 to 13, characterized by further comprising rotation means (114, 115) for rotating at least one of said pair of holding means (108, 109) about a shaft (106, 107) perpendicular to a holding surface.
18. The apparatus according to claim 17, characterized in that said rotation means (114, 115) rotates said holding means (108, 109) when said separation means (110) separates the member (101).
19. The apparatus according to claim 17 or 18, characterized in that said separation means (110) separates the member using a stream of a liquid, and said rotation means (114, 115) rotates said holding means (108, 109) to remove the liquid sticking to the member held by said holding means (108, 109) after the member (101) is separated by said separation means (110).
20. The apparatus according to any one of claims 1 to 19, characterized by further comprising a chamber (400) for covering said apparatus.
21. The apparatus according to claim 20, characterized in that said chamber (400) has a shutter (503) capable of opening/closing.
22. The apparatus according to claim 21, characterized by further comprising transfer means (501) for transferring the member (101) to be processed to said manipulation means (150, 160) and receiving the separated member (101a, 101c) from said manipulation means (150, 160), said transfer means (501) being arranged outside said chamber (400) and transferring/receiving the member (101) to/from said manipulation means (150, 160) while opening said shutter (503).
23. The apparatus according to claim 21 or 22, characterized in that said shutter (503) is closed at least when the member is separated by said separation means (110).
24. The apparatus according to claim 22 or 23, characterized by further comprising positioning means (507) for positioning the member (101) to be processed with respect to said manipulation means (150, 160).
25. The apparatus according to any one of claims 1 to 24, characterized in that the member (101) to be separated has a fragile layer (101b) as a separation layer, and the fragile layer (101b) is substantially parallel to the major surface of the member.
26. A processing apparatus for processing a member (101), characterized by comprising:
- manipulation means (150, 160) for changing a direction of a major surface of the member (101);
- rotation means (151, 161) for rotating the member (101) about a shaft (106, 107) perpendicular to the major surface; and
- processing means (110) for processing the member (101) while said rotation means (151,

- 161) is rotating the member (101),  
 wherein said manipulation means (150, 160)  
 receives the member (101) with the major sur-  
 face whose direction matches with a first direc-  
 tion, matches the direction of the major surface  
 with a second direction, and moves the mem-  
 ber (101) to a position where said processing  
 means (110) can process the member, and  
 also matches the direction of the major surface  
 of the member (101) which has been pro-  
 cessed by said processing means (110) with the  
 first direction.
27. The apparatus according to claim 26, characterized  
 in that the first and second directions are substan-  
 tially perpendicular to each other.
28. The apparatus according to claim 26 or 27, charac-  
 terized in that the first direction is a direction in  
 which the major surface of the member (101) is  
 substantially horizontal.
29. The apparatus according to any one of claims 26 to  
 28, characterized in that said processing means  
 (110) processes the member (101) using a liquid,  
 and said rotation means (151, 161) rotates the  
 member (101) to remove the liquid sticking to the  
 member (101) after the member (101) is processed  
 by said processing means (110).
30. A processing apparatus for processing a member  
 (101), characterized by comprising:
- holding means (108, 109) for holding the mem-  
 ber (101);  
 manipulation means (150, 160) for changing a  
 direction of a holding surface of said holding  
 means (108, 109);  
 processing means (110) for processing the  
 member (101) held by said holding means  
 (108, 109); and  
 rotation means (114, 115) for rotating said  
 holding means (108, 109) holding the member  
 (101) about a shaft (106, 107) perpendicular to  
 the holding surface when said processing  
 means (110) is processing and/or has pro-  
 cessed the member (101),  
 wherein said manipulation means (150, 160)  
 matches the direction of the holding surface  
 with a first direction when said holding means  
 (108, 109) is to receive the member (101) to be  
 processed, matches the direction of the holding  
 surface of said holding means (108, 109) with a  
 second direction after said holding means  
 (108, 109) receives and holds the member  
 (101), and moves said holding means (108,  
 109) to a position where said processing  
 means (110) can process the member (101),  
 and also matches the direction of the holding  
 surface of said holding means (108, 109) with  
 the first direction after processing by said  
 processing means (110) is complete.
31. The apparatus according to claim 30, characterized  
 in that the first and second directions are substan-  
 tially perpendicular to each other.
32. The apparatus according to claim 30 or 31, charac-  
 terized in that the first direction is a direction in  
 which the major surface of the member (101) is  
 substantially horizontal.
33. The apparatus according to any one of claims 30 to  
 32, characterized in that said processing means  
 (110) processes the member (101) using a liquid,  
 and said rotation means (114, 115) rotates the  
 member (101) to remove the liquid sticking to the  
 member (101) after the member (101) is processed  
 by said processing means (110).
34. A separating method of separating a member  
 (101), characterized by comprising:
- the reception step of receiving the member  
 (101) with a major surface whose direction  
 matches with a first direction;  
 the manipulation step of matching the direction  
 of the major surface of the member (101) with a  
 second direction; and  
 the separation step of separating the member  
 (101) using a stream of a fluid.
35. The method according to claim 34, characterized  
 by further comprising the second manipulation step  
 of matching a direction of a major surface of at least  
 one member of the members (101a, 101c) sepa-  
 rated in the separation step with the first direction.
36. The method according to claim 34, characterized  
 by further comprising the second manipulation step  
 of matching directions of major surfaces of the  
 members (101a, 101c) separated in the separation  
 step with the first direction.
37. The method according to any one of claims 34 to  
 36, characterized in that the first and second direc-  
 tions are substantially perpendicular to each other.
38. The method according to any one of claims 34 to  
 37, characterized in that the first direction is a direc-  
 tion in which the major surface of the member (101)  
 is substantially horizontal.
39. The method according to any one of claims 34 to  
 36, characterized in that the member to be pro-  
 cessed comprises a plate member (101), and the

- separation step comprises cutting the plate member (101) in a direction of plane to separate the member into two plate members (101).
40. The method according to claim 39, characterized in that the second direction is a direction in which the major surface of the plate member (101) is substantially vertical, and the separation step comprises ejecting the fluid toward the plate member (101) in the vertical direction to separate the plate member (101) into two plate members (101a, 101c).
41. The method according to claim 40, characterized in that the first direction is a direction in which the major surface of the plate member (101) is substantially horizontal.
42. The method according to any one of claims 39 to 41, characterized in that the separation step comprises holding the plate member (101) by sandwiching the member from two surface sides.
43. The method according to any one of claims 34 to 42, characterized in that the separation step comprises separating the member (101) using the stream of a fluid while rotating the member (101) to be processed about a shaft (106, 107) perpendicular to the major surface.
44. The method according to any one of claims 34 to 43, characterized in that the separation step comprises separating the member (101) using a liquid, and the method further comprises rotating at least one of the members (101a, 101c) separated to remove the liquid sticking to the member (101a, 101c) after the member (101) is separated in the separation step.
45. The method according to any one of claims 34 to 44, characterized in that the separation step is executed in a chamber (400) to prevent the fluid from scattering.
46. The method according to any one of claims 34 to 45, characterized in that the member (101) to be processed has a fragile layer (101b) as a separation layer, and the fragile layer (101b) is substantially parallel to the major surface of the member (101).
47. The method according to claim 46, characterized in that the fragile layer (101b) comprises a porous layer.
48. The method according to claim 46, characterized in that the fragile layer (101b) comprises a layer having microcavity.
49. The method according to claim 46, characterized in that the member (101) to be processed is prepared by bonding at least two plate members (10, 20), and at least one of the two plate members (10, 20) comprises a semiconductor substrate.
50. The method according to claim 49, characterized in that the semiconductor substrate comprises a single-crystal silicon substrate (10, 20).
51. The method according to claim 46, characterized in that the member (101) to be processed is prepared by bonding at least two plate members (10, 20), and at least one of the two plate members (10, 20) comprises an insulating substrate.
52. The method according to claim 51, characterized in that the insulating substrate comprises a quartz substrate.
53. The method according to claim 46, characterized in that the member (101) to be processed is prepared by bonding at least two plate members (10, 20), and at least one of the two plate members (10, 20) comprises a transparent substrate.
54. The method according to claim 47, characterized in that the member (101) to be processed is prepared by bonding a first substrate (10) sequentially having a nonporous layer (13, 15) and a porous layer (12) inward from a surface to a second substrate (20) via the nonporous layer (13, 15).
55. The method according to claim 54, characterized in that the nonporous layer (13, 15) has a single-crystal silicon layer (13).
56. The method according to claim 55, characterized in that the nonporous layer (13, 15) has an insulating layer (15) on the single-crystal silicon layer (13).
57. The method according to claim 56, characterized in that the insulating layer (15) is formed from a silicon oxide.
58. The method according to claim 54, characterized in that the second substrate (20) comprises an insulating substrate.
59. The method according to claim 54, characterized in that the second substrate (20) comprises a transparent substrate.
60. The method according to claim 54, characterized in that the second substrate (20) comprises a quartz substrate.
61. The method according to any one of claims 54 to

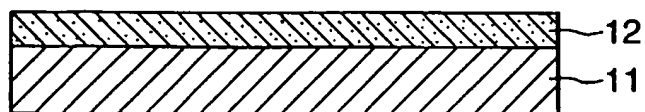
60, characterized in that the porous layer (101b) is formed by anodizing a single-crystal silicon substrate (11).

62. The method according to claim 48, characterized in that the member (101) to be processed is prepared by bonding a second substrate (20) to a surface of a first substrate (10) incorporating a microcavity layer. 5
63. The method according to claim 62, characterized in that the microcavity layer is formed by implanting ions into a single-crystal silicon substrate (11). 10
64. The method according to any one of claims 34 to 63, characterized in that water is used as the fluid. 15
65. A semiconductor substrate manufacturing method characterized by comprising the steps of: 20
- preparing a first substrate (10) incorporating a porous layer (12) or a microcavity layer; bonding the first substrate (10) to a second substrate (20) to prepare a bonded substrate stack; 25
- separating the bonded substrate stack into a first substrate side (10') and a second substrate side (10", 20) using the porous layer (12) or microcavity layer as a separation region by using the separating method of any one of claims 34 to 45; and 30
- removing the porous layer (12") or microcavity layer remaining on the second substrate side (10", 20). 35
66. The method according to claim 65, characterized by further comprising the step of, after the bonded substrate stack is separated, removing the porous layer (12') or microcavity layer remaining on the first substrate side (10') to reuse the first substrate. 40
67. The method according to claim 65, characterized in that the porous layer (12) is formed by anodizing a semiconductor substrate (11). 45
68. The method according to claim 65, characterized in that the microcavity layer is formed by implanting ions in a semiconductor substrate (11).
69. A semiconductor substrate formed by the method of any one of claims 65 to 68. 50

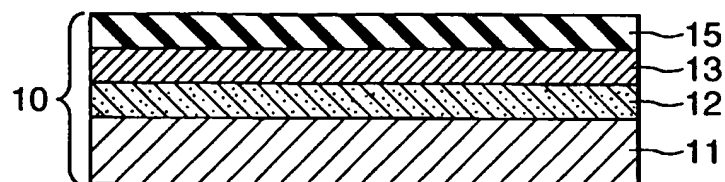
55



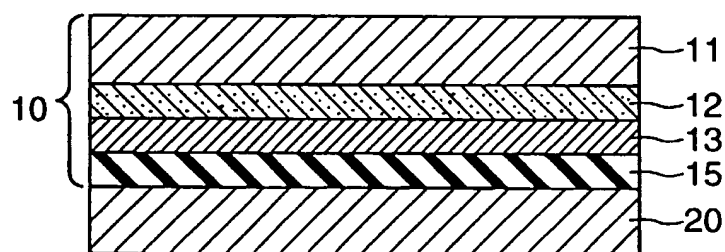
**FIG. 1A**



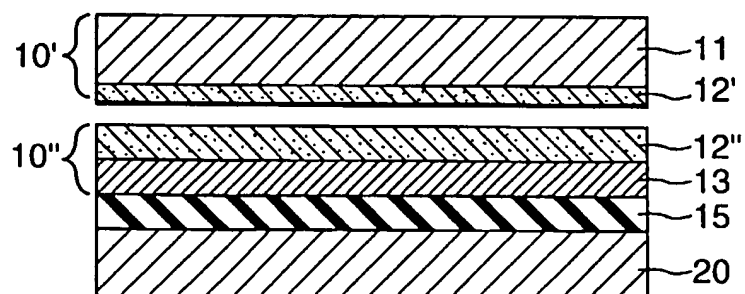
**FIG. 1B**



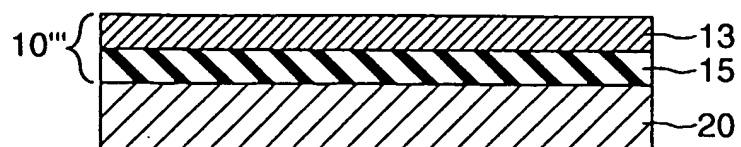
**FIG. 1C**



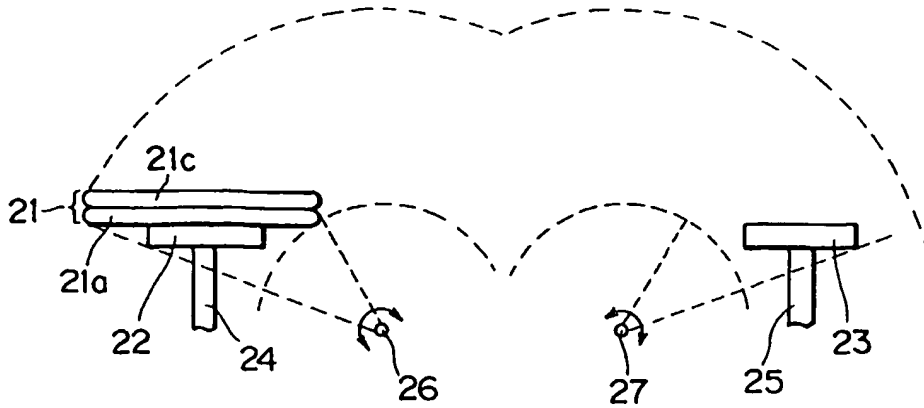
**FIG. 1D**



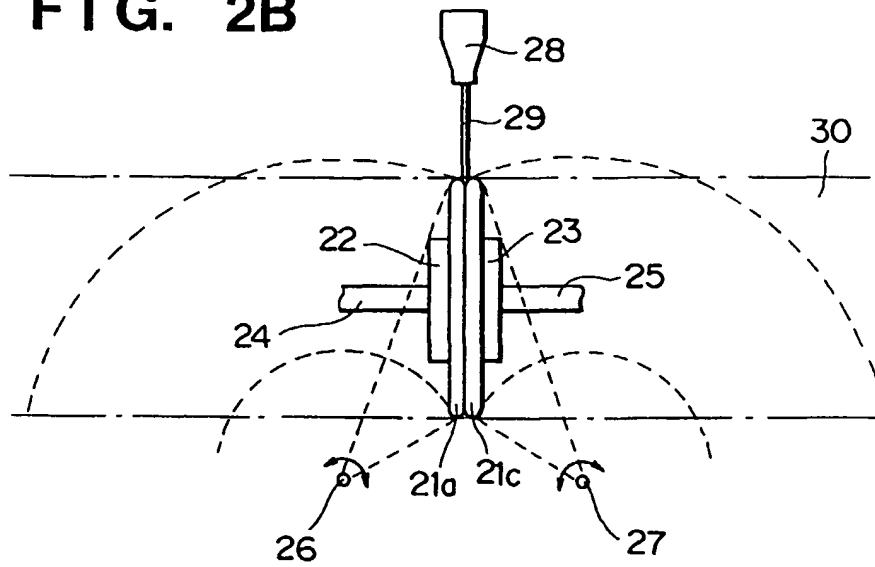
**FIG. 1E**



**FIG. 2A**



**FIG. 2B**



**FIG. 2C**

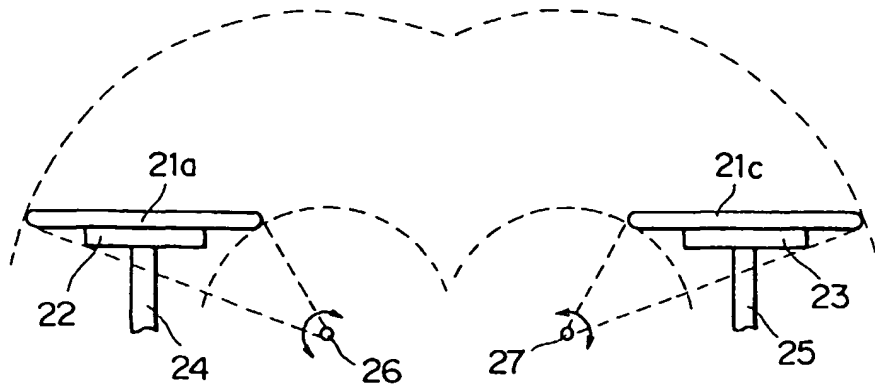




FIG. 4

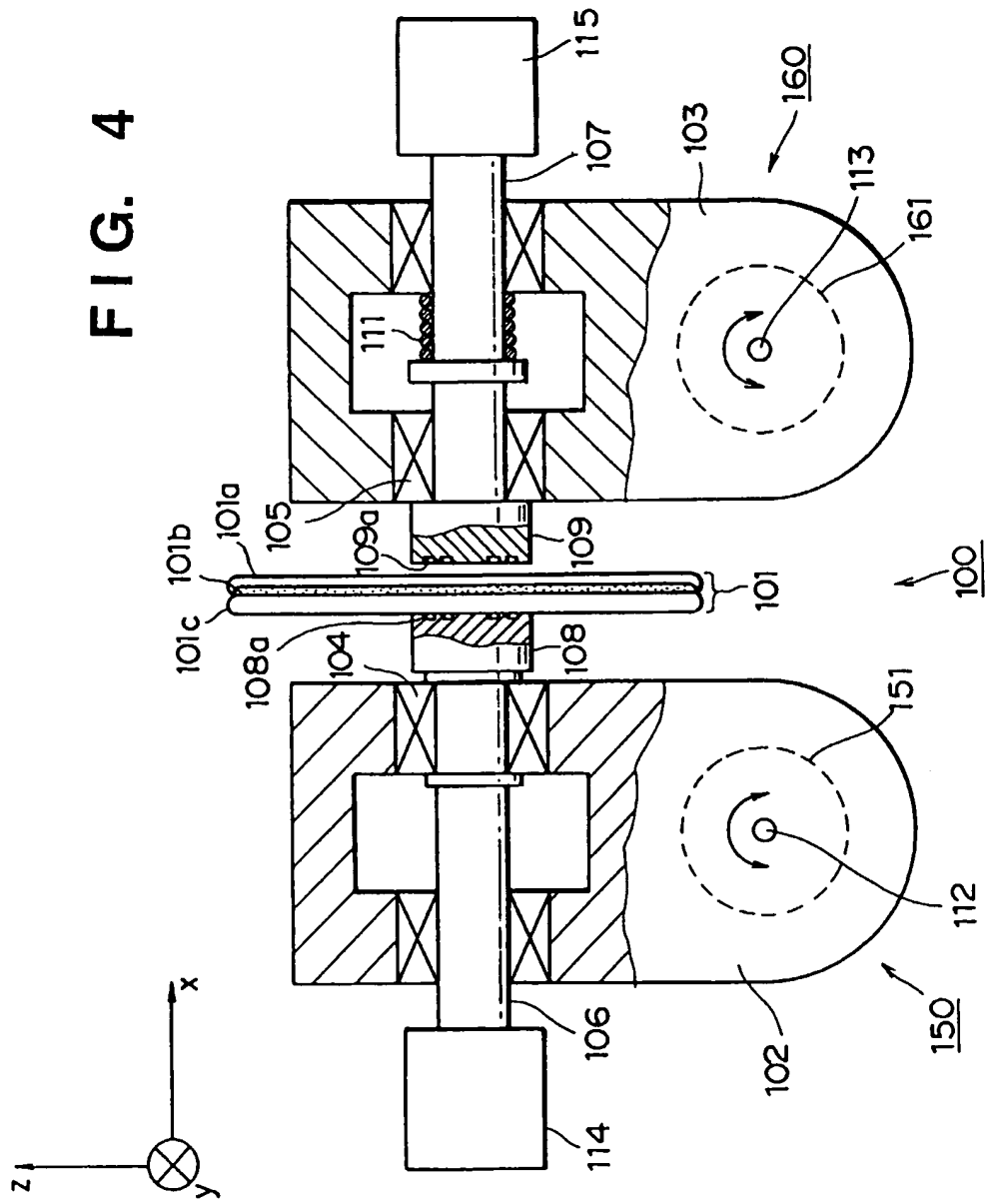
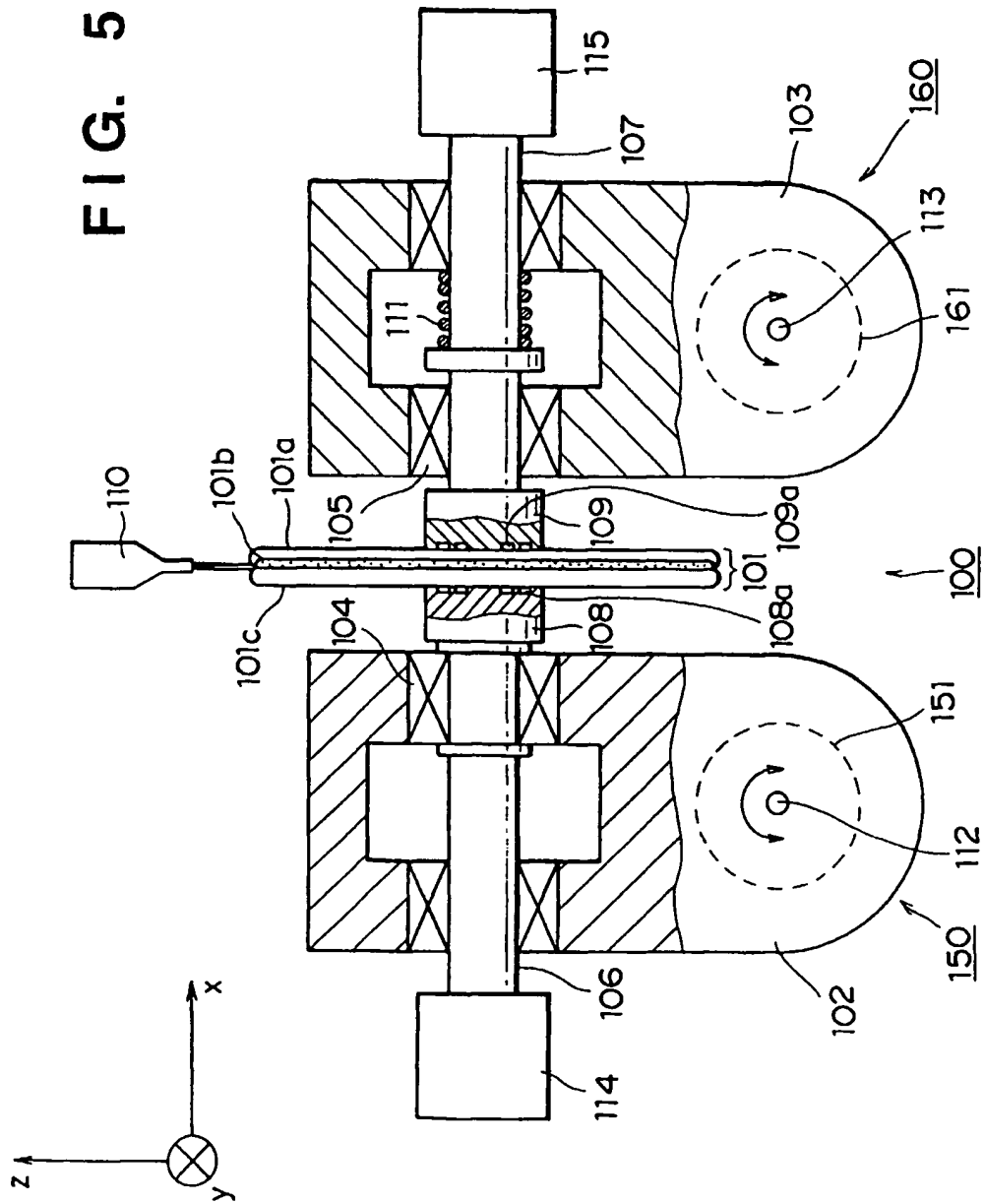
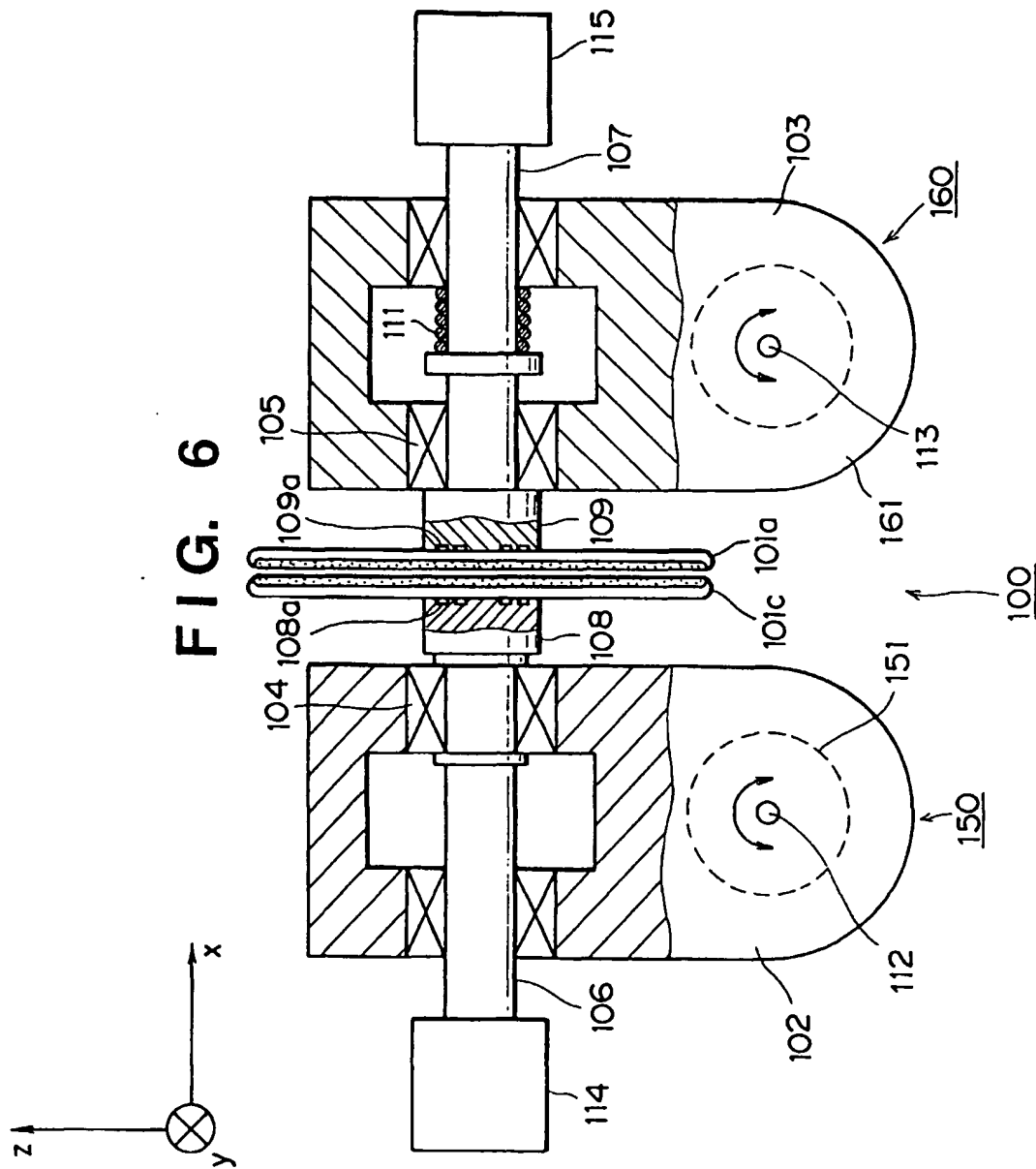
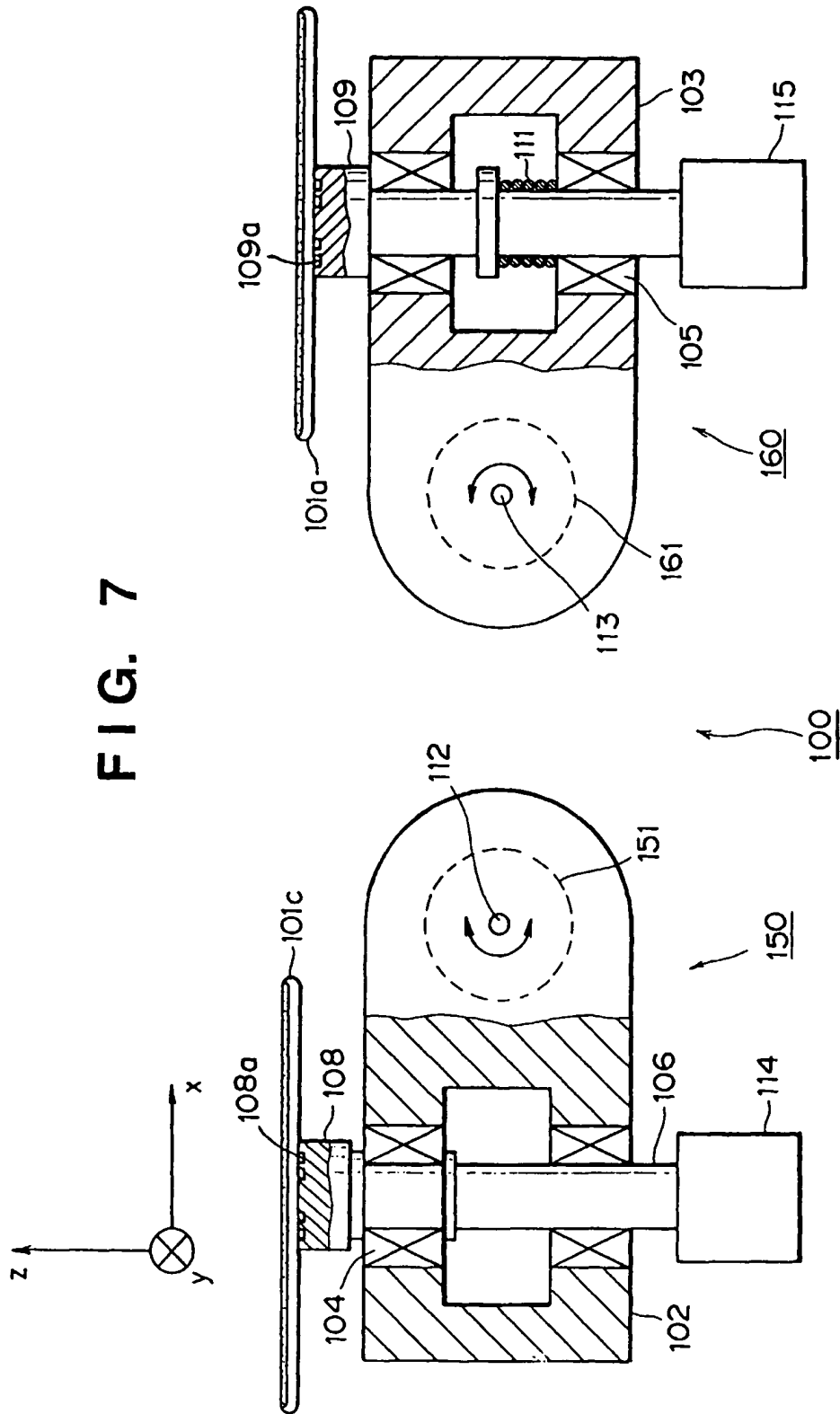


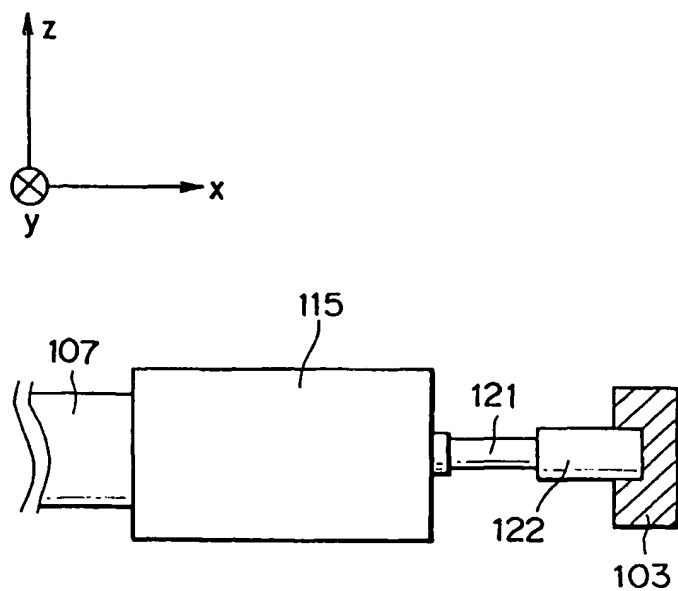
Fig. 5



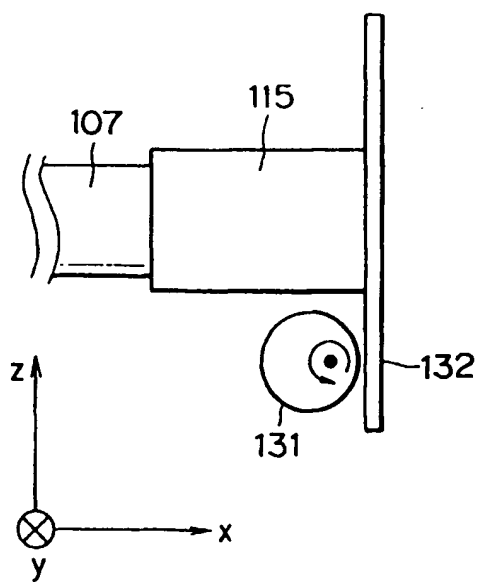




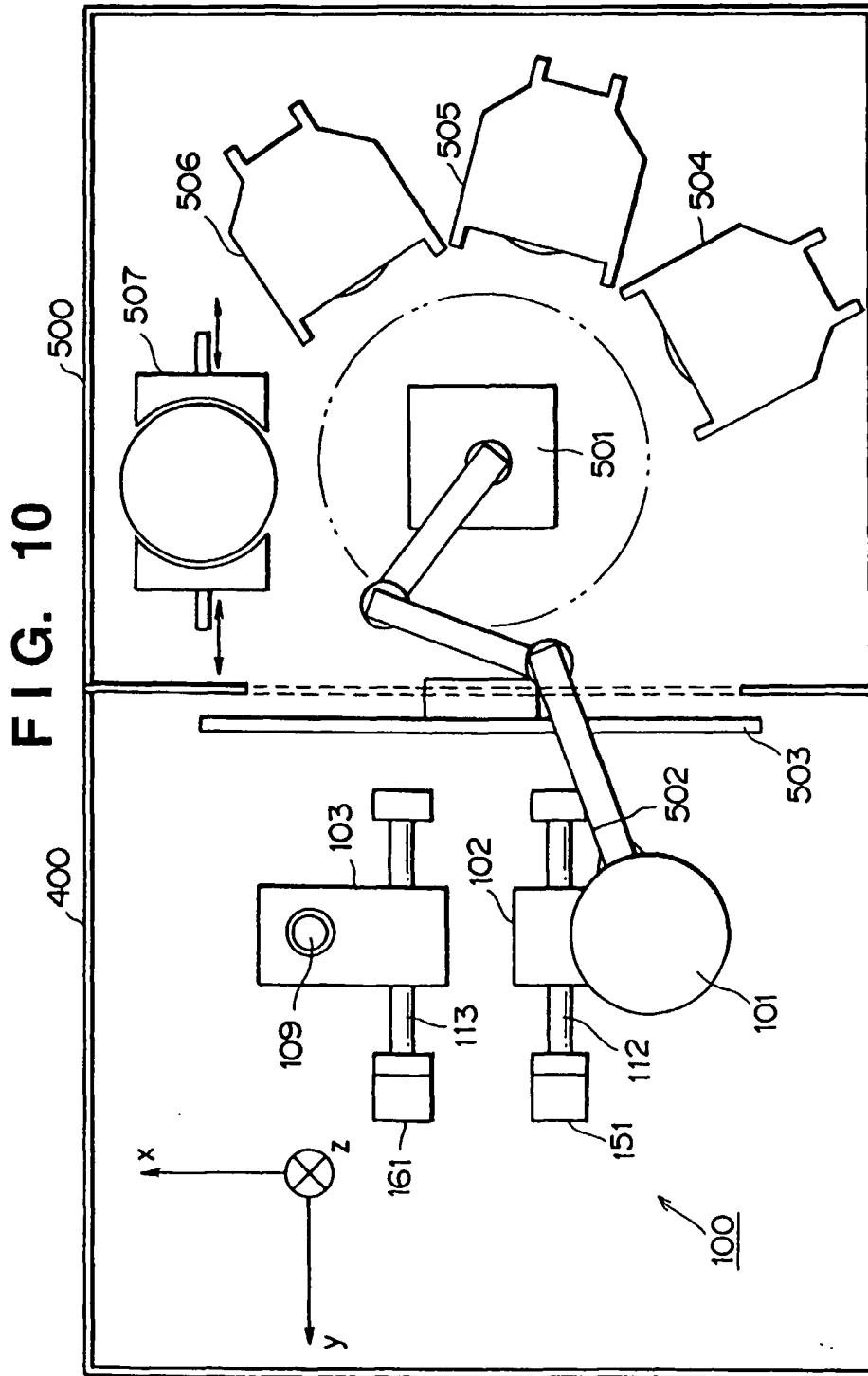
**FIG. 8**



**FIG. 9**







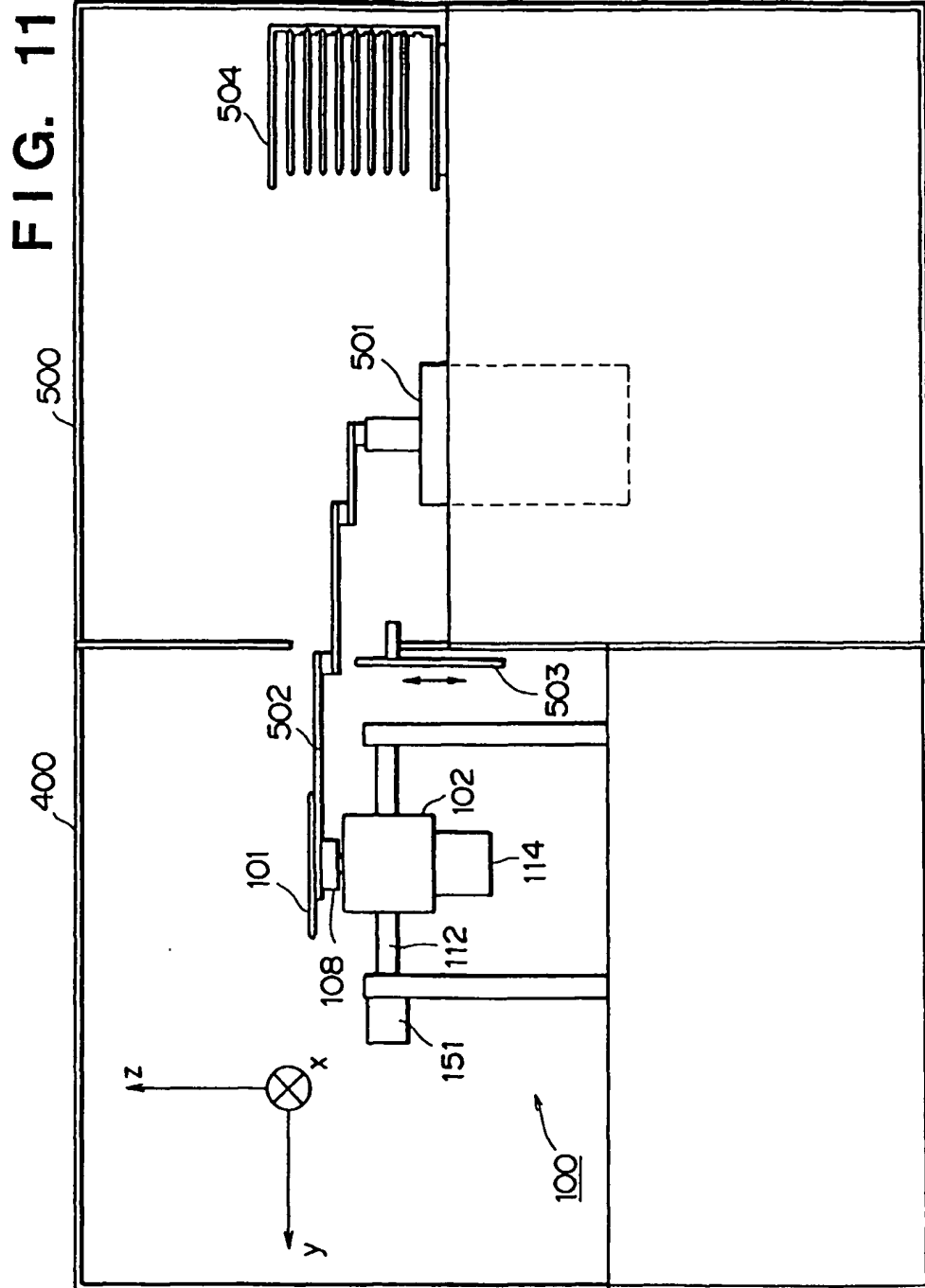


FIG. 12

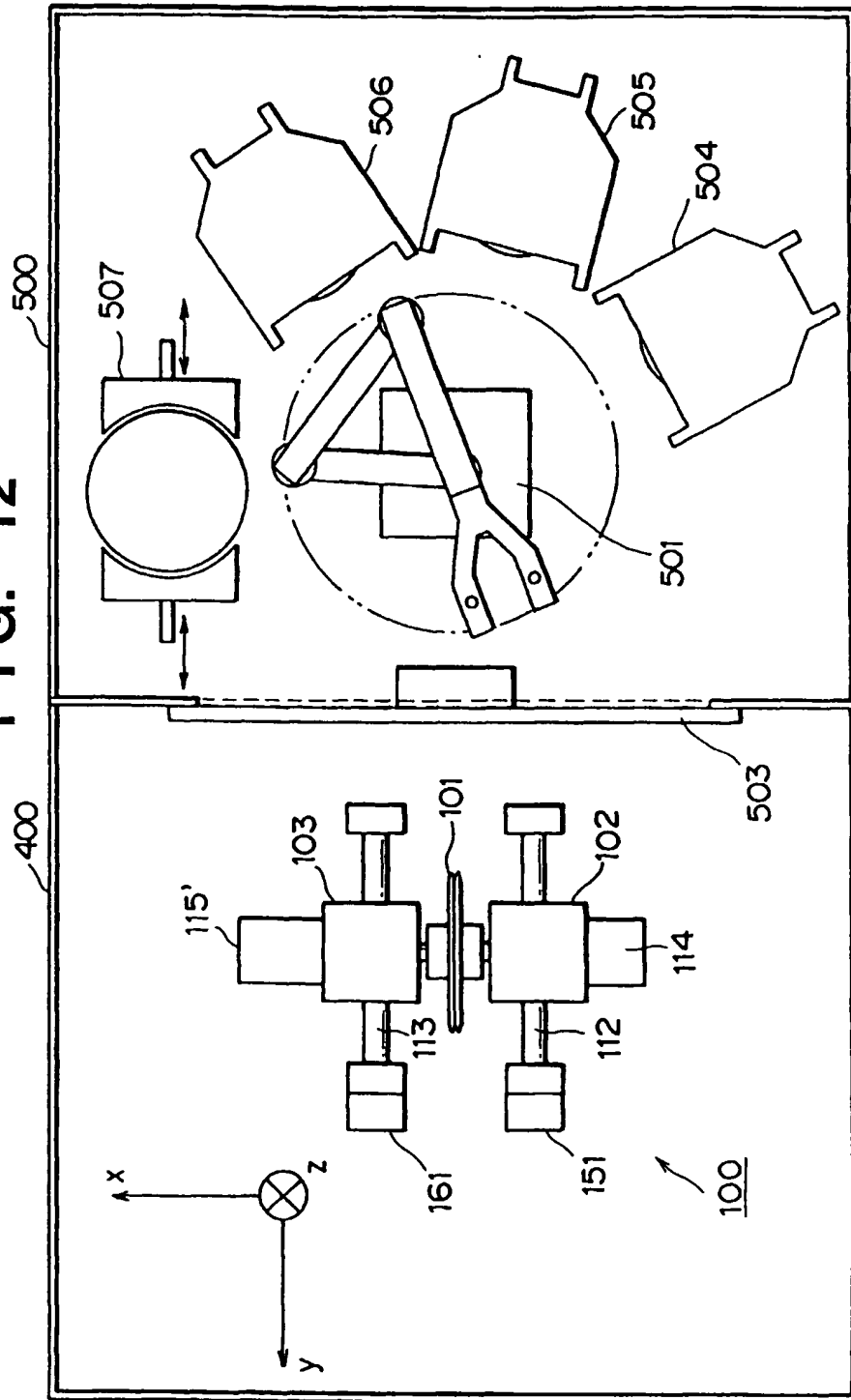
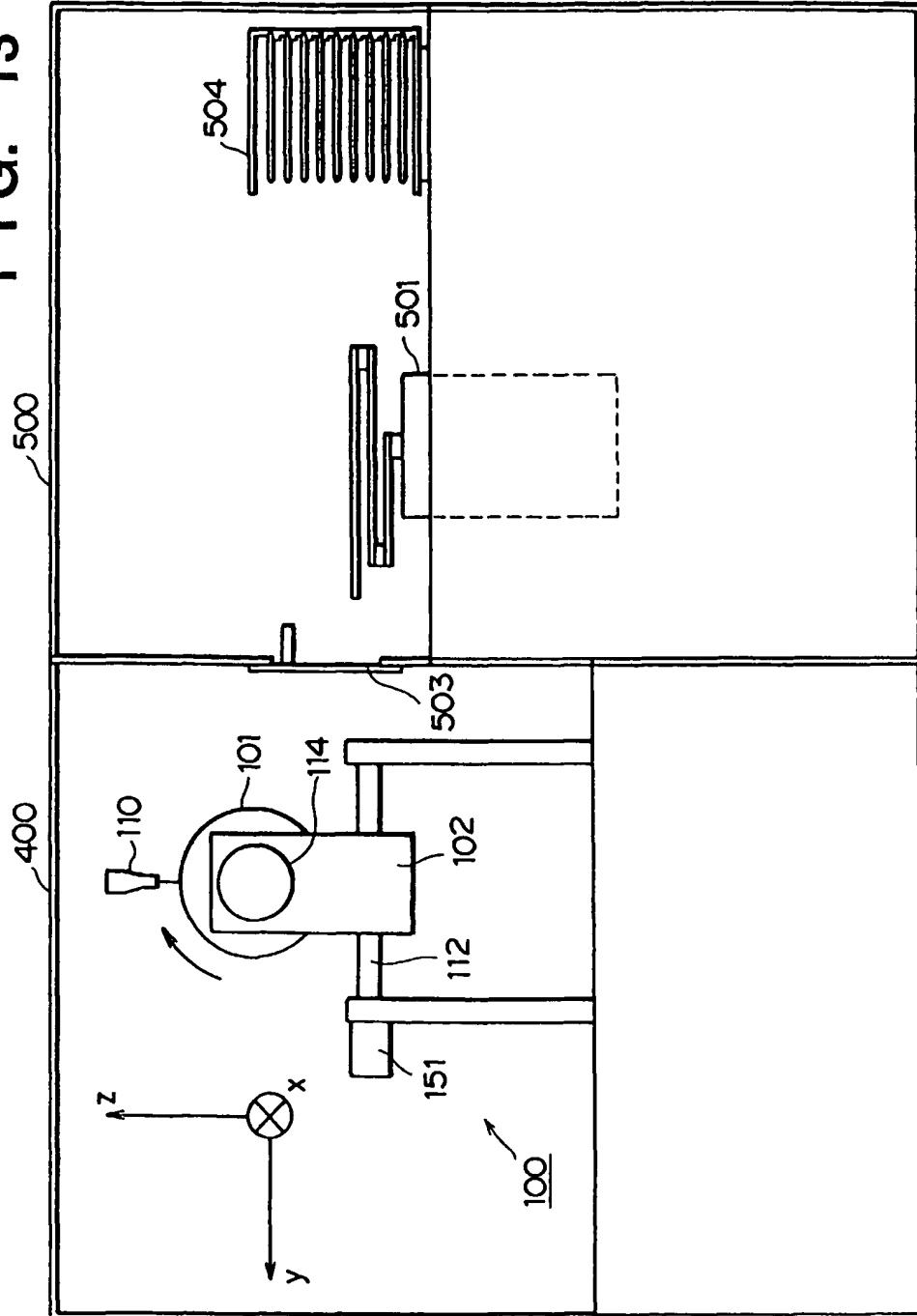


FIG. 13



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(88) Date of publication A3:  
**19.09.2001 Bulletin 2001/38**

(51) Int Cl.7: **H01L 21/00**

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**MC NL PT SE**  
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**Tokyo (JP)**
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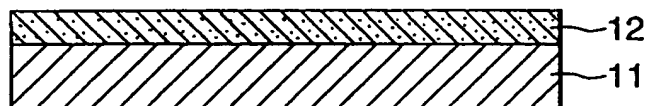
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**BERESFORD & Co.**  
**High Holborn**  
**2-5 Warwick Court**  
**London WC1R 5DJ (GB)**

(54) **Member separating apparatus and processing apparatus**

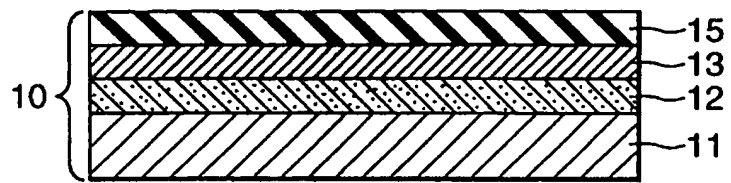
(57) This invention is to prevent a substrate from dropping when it is transferred/received to/from a separating apparatus. The support surfaces of substrate holding portions (22, 23) are made horizontal, and a substrate (21) to be separated is mounted on one substrate holding portion (22) in a horizontal state (2A). The substrate holding portions (22, 23) are pivoted about rotary shafts (26, 27), respectively, to make the support surfaces of the substrate holding portions (22, 23) vertical so that the substrate (21) is sandwiched by the sub-

strate holding portions (22, 23) (2B). The substrate holding portions (22, 23) are rotated about rotary shafts (24, 25), respectively, and simultaneously, high-pressure, high-speed water is ejected from an ejection nozzle (28) to separate the substrate (21) into two substrates (21a, 21c). The substrate holding portions (22, 23) are pivoted about the rotary shafts (26, 27), respectively, to make the support surfaces horizontal (2C). With this arrangement, the substrate can be supported from the lower side and transferred in the horizontal state.

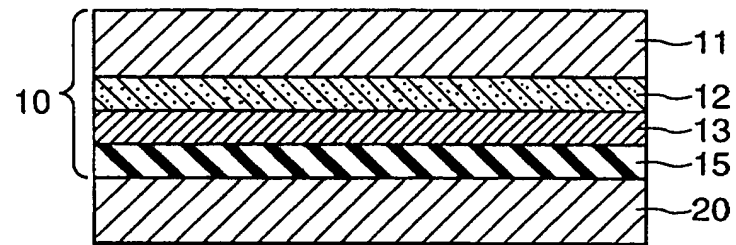
**FIG. 1A**



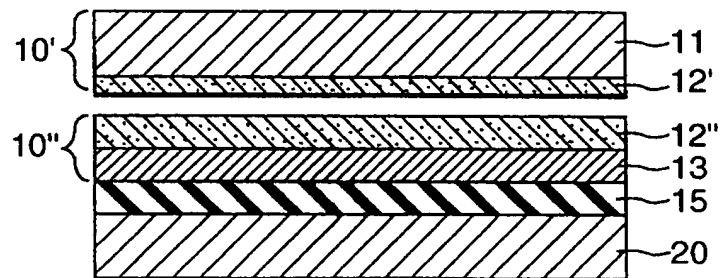
**FIG. 1B**



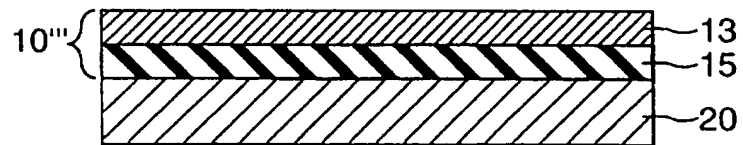
**FIG. 1C**



**FIG. 1D**



**FIG. 1E**





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# EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 2393

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 07, 31 March 1999 (1999-03-31) & JP 09 167724 A (SAMSUNG ELECTRON CO LTD), 24 June 1997 (1997-06-24)	1,5,6, 25,34, 38,39, 46, 49-51,64 3,26,30	H01L21/00
A	* abstract * * figures 3,4 * & US 5 783 022 A (CHA ET AL.) 21 July 1998 (1998-07-21) * the whole document *		
Y	EP 0 383 391 A (PHILIPS NV) 22 August 1990 (1990-08-22)	1-4,6, 9-15,17, 18,20, 25,26, 28,30, 32, 34-36, 38,39, 42,43, 45,46, 49-53,64	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01L
	* column 2, line 29 - line 53 * * column 4, line 14 - line 26 * * claims 7-10 * * figures 3-5,14-17 * --- -/-		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 24 July 2001	Examiner Giordani, S
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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Application Number  
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**CLAIMS INCURRING FEES**

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

**LACK OF UNITY OF INVENTION**

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:





European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 2393

DOCUMENTS CONSIDERED TO BE RELEVANT				
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cls)	
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Y	EP 0 793 263 A (CANON KK) 3 September 1997 (1997-09-03) * figures 6, 7 * * column 18, line 15 - column 20, line 22 *	65-69		
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P, X	EP 0 843 345 A (CANON KK) 20 May 1998 (1998-05-20) * page 7, line 18 - line 54 * * page 11, line 40 - line 46 * * figures 1A-1E *	65-69		
The present search report has been drawn up for all claims				
Place of search THE HAGUE		Date of completion of the search 24 July 2001	Examiner Giordani, S	
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons S : member of the same patent family, corresponding document</p>				

EPO FORM 1503 03/02 (P04001)



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LACK OF UNITY OF INVENTION  
SHEET B

Application Number  
EP 99 30 2393

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-64

Separating method and apparatus for processing a member comprising:

- holding means for holding the member;
- manipulation means for changing direction of a major surface of the member;
- processing means for processing the member held by said holding means, said processing means being in particular separator means for separating the member using a stream of fluid;
- rotation means for rotating said holding means holding the member about a shaft perpendicular to the holding surface when said processing means is processing and/or has processed the member.

2. Claims: 65-69

Method of manufacturing a semiconductor substrate with the steps of:

- preparing a first substrate incorporating a porous layer or a microcavity layer;
- bonding the first substrate to a second substrate to prepare a bonded substrate stack;
- separating the bonded substrate stack into a first substrate side and a second substrate side using the porous layer or microcavity layer as a separation region, where the separation step of separating the members is performed using a vertical stream of fluid;
- removing the porous layer or microcavity layer remaining on the second substrate.



European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 2393

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
P, X	WO 98 52216 A (HENLEY FRANCOIS J ;CHEUNG NATHAN W (US); SILICON GENESIS CORP (US)) 19 November 1998 (1998-11-19) * page 9, line 16 - page 11, line 23 * * figure 6A *	65,66, 68,69	
A	EP 0 797 258 A (SONY CORP) 24 September 1997 (1997-09-24) * column 17, line 20 - column 18, line 45 * * column 21, line 45 - column 23, line 24 * * figures 2-8 *	65-69	
A	EP 0 767 486 A (CANON KK) 9 April 1997 (1997-04-09) * column 19, line 9 - column 20, line 11 * * column 27, line 9 - column 30, line 14 * * example 5 * * figures 4A-4F *	65-69	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 24 July 2001	Examiner Giordani, S
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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